An Introduction to

the History of Science

in Non-Western Traditions

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History of Science Society
Seattle
2008

HISTORY OF SCIENCE IN NON-WESTERN TRADITIONS

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INTRODUCTION:
HISTORY OF SCIENCE
IN NON-WESTERN TRADITIONS

Non-Western perspectives continue to gain significance in history and other disciplines. This publication, now in its second edition, aims to introduce the pursuit of science in Non-Western traditions through a series of brief essays and reading lists, in the style of a richly annotated course syllabus. It is an outline and guide to resources, not a complete survey text.

Delving into "non-Western science," one quickly finds that concepts of "Western," "Non-Western," and "science" are problematic—as many of our contributors reveal. If "science" is defined according to norms and concepts that emerged during the period of the early modern Western Scientific Revolution, the very notion of science in a traditional, non-Western culture may be obscure. On the other hand, because cultural traditions have blended over the past several centuries, what currently distinguishes "Western" from "non-Western" may no longer be clearly evident. As well, the rich scholarship manifested in the contributions to this volume discourages efforts to rigidly differentiate among "science," "technology," and medicine." For example, our contributors highlight the astronomy of the early Chinese, the navigational techniques of Pacific islanders, and the ancient medical knowledge of sub-Saharan Africans—each seemingly embodying science and technology inseparably. We anticipate that materials in this collection will promote healthy consideration of the relationship between science and technology.

We have not included a contribution on medieval Arabic science (though clearly non-European) because historians of science have acknowledged its role in contributing to the rise of science in modern Europe—good texts and resources dealing with that tradition are readily available. On the other hand, we include contemporary science in other non-European regions such as Latin America and Japan, where science has followed a "Western" model but has been overlooked by European and North American historians of science until recently. Essays in this collection that deal with adoption or integration of Western science in cultures where it did not originally develop can lead the reader to important insights into how power and culture affect the pursuit of science.

The collection includes contributions on China, India, Africa, Latin America, Native America, Australia and the Pacific, and Japan. Each chapter begins with an introduction that aims to address the scope, noteworthy scientific achievements, and major figures in each tradition. A list of major references appears that may serve as first purchases for those planning to pursue the topic in more depth. A list of noteworthy sources for addressing current scholarship also is included: significant journals, newsletters, websites, listservs, study centers, or professional organizations where someone can update the sources on the reading lists, review the latest research, or contact professionals in the field.

Each chapter then presents a six-day "syllabus" with a brief synopsis for each day's theme or focus. Each day includes a list of student readings—1-1½ hours of introductory material. Additional recommended extended reading appears also for the student or teacher interested in pursuing the day's topic in more depth. As appropriate, audio-visual materials are cited along with suggested topics for further research at the end of some chapters.

This volume is available both in print and online at the History of Science Society's website. The website, in particular, allows us to provide periodic revisions and supplemental materials, and we invite you to check occasionally for updates.

We hope that this small volume will prove useful to seasoned historians of science, as well as to graduate or undergraduate students in the history of science who want to expand their repertoires. In addition, we hope that it will serve ethnic/minority students who want to deepen their knowledge of science in a particular tradition, and college or K-12 science teachers who want to engage students in the humanistic dimensions of science.

We owe many thanks to our contributors, who volunteered their efforts and pursued this project despite their crowded schedules. In addition, we would like to acknowledge the support of Keith Benson, Jay Malone, and the staff of the History of Science Society in fostering this undertaking from its initial conception to the published volume.

Robert DeKosky
Douglas Allchin

CHINA

William C. Summers

INTRODUCTION

The analytical categories "science" and "medicine", as understood in the contemporary Western sense, do not map well onto those activities in traditional East Asia which were aimed at understanding and manipulating the natural world. The modern Western notions of "science" and "medicine" in their 20th-21st century form do not have accurate analogies for most of premodern East Asia. Thus, questions such as "why did the scientific revolution not happen in China?" are simply not very useful or, in fact, meaningful. One of the really informative aspects of cross-cultural studies is the realization that the study, understanding, and mastery of the natural world does not have a unique and universal trajectory applicable to all cultures. While it is often convenient to speak of "Chinese Science" or "Chinese Medicine", it is important to keep in mind that these terms are simply shorthand, using familiar Western categories, for a more nuanced and complex set of conceptual categories. What the peoples of East Asia have done since earliest times, and what they have in common with all known civilizations, in their various ways of making sense of the natural world. Today we call those activities, in a broad sense, "science". It is important, however, to keep in mind the limitations and pitfalls that uncritical applications of such concepts, cultural assumptions and philosophic principles can produce when applied to the study of cultures of other places and other times.

Archeological evidence for scientific and technological knowledge in China extends at least to the Neolithic period (ca. 6000 BCE) while written material is available from as early as the Shang period (ca. 1700 - 1025 BCE). Early traditions, dating from the Shang, include divinations written in the precursor to modern Chinese script on flat bones and turtle shell ("oracle bones") and technically-advanced bronze castings. The Zhou dynasty (1122 - 256 BCE) was characterized by the development of the dominant philosophical schools of traditional Chinese thought: Daoism, Confucianism, Moism, and Legalism. By the Han dynasty (206 BC - 220 CE) comprehensive cosmological views of the universe had been developed by the Daoists based on a few universal principles: yin and yang complementarity, the relations and correspondences of wu xing (the five phases of the universe: wood, fire, earth, metal, and water), together with notions of qi (vital force, or "matter-energy") and li (natural order, or organizing principle). The most coherant and comprehensive exposition of this basic cosmology is found in the *Huai-nan tzu* (ca. 139 BCE), a summary and compilation of learning sponsored by Liu An, King of Huai-nan.

One theme in Daoist thought which is of major interest is the quest for elixirs of immortality. This activity was both theoretical and experimental, and led to the development of the Chinese "alchemical" tradition, not concerned with transmutation of metals as in the West, but in the formation of substances which

could confer immortality and sagehood. Much knowledge of the properties and behavior of natural substances emerged from this work. This tradition started at least 2 millenia ago and was well-established by the end of the Three Kingdoms period (220-265 CE) when Ge Hong (Ko Hung) compiled his well-known work on daoist "alchemical" techniques, *Bao pu tzi (Pao-p'u tzu*) (ca. 317 CE).
Another approach to the natural world was through the organization of plants, animals, and minerals according to their uses by mankind in the form of books called "ben cao" (often translated as pharmacopoeia). The ben cao are texts that include natural history, biological classifications, and practical and medical uses of natural materials, in modern terms, biology, geology and medicine. By the Ming dynasty (1368 - 1644 CE), great, comprehensive ben cao texts had been compiled that are still used in China today, for example, the *Ben cao gang mu* (1596 CE), often called "The Great Pharmacopoeia", by Li Shi-zhen.

Also during the Ming dynasty, China took an active interest in the learning of the West that was brought by Jesuit missionaries. Because of the importance of calendrical science in Chinese cosmology and thought and its role in political affairs, the Ming rulers were especially interested in the recent advances in European astronomy and the associated mathematical approaches. The interplay of two quite different cosmologies during this period gives an especially interesting opportunity to examine the role of politics, culture and tradition on the development of science and the change in beliefs about nature.

By the time of the Qing dynasty (1644 - 1911 CE) the many interactions between China and the West provoked reactions within China, at one extreme, to adopt Western scientific learning in toto, and at the other extreme, to reject it completely in favor of indigenous traditions. While other Asian countries (e.g., Japan and India) were able to follow their own paths to modernization, China was racked by internal strife and external assaults from the mid-nineteenth century to the mid-twentieth century. During this period of about 100 years, China struggled to modernize its science, education, technology and industries under the handicaps of civil wars and rebellions, and probably most importantly, lack of capital for investment in these essential activities. For the historian of science, then, this period in Chinese history affords a clear example of the role of economic and social factors in the course of the scientific enterprise.

In the twentieth century, China has struggled to find its "national philosophy of life" through wrenching debates in the early 1920s and to decide on the proper balance between politics and science since the 1950s. The role of Marxist-Leninist-Mao ideology in scientific inquiry is clear in the case of genetic research in China under the influence of the Soviet biologist Trofim Lysenko. Likewise, the role of national politics can be studied in scientific and technological projects such as the development of nuclear weapons and the recent construction of the massive hydrological project on the Yangtze river known as the Three Gorges Dam.

One approach to the study of some of these themes might be organized around the Chinese achievements in cosmology, technology, and modern science.

The stability and durability of the Chinese cosmology—that is, the yin-yang and wu xing model—is quite remarkable. It has survived for over 2000 years

and is still alive and well in both folk beliefs and in traditional Chinese medicine. It has wide explanatory power and adaptability.

The achievements of Chinese artisans, engineers, and scientists in papermaking, metallurgy, hydrology, agriculture and medicine are well-described in the Western literature and provide interesting comparisons with Western approaches to similar practical problems.

The particular Chinese way of approaching the problems of how science relates to politics and the state is another possible way to study science in China. The interplay of ideology of the state and culture and the ideologies of scientific inquiry has been of concern in China for a long time. While it has surfaced in the twentieth century in more obvious ways (e.g., genetics, economics, physics), in earlier times daoist research on elixirs of immortality had political overtones, and "independent thinking" often led to politically subversive ideas.

Another approach to better understand science in China is to study the works and lives of major figures for whom significant descriptive material is available in English. Four such individuals, representing chronologically different periods, are the daoist "alchemist," Ge Hong (283-343), the Sung polymath, Shen Gua (1031-1095), the great ben cao author, Li Shi-zhen (1518-1593), and the modern architect of public health in China, Wu Lien-te (1879-1960).

Resources

The available literature on science in China falls into two main categories: scholarly work and popularized works on exoticism. Western readers have been fascinated with tales of the exotic East at least since the days of Marco Polo. Even today, there is a large market for uncritical accounts and explanations of the "mysteries of the East". Much of this is published under the rubric of health advice or "Eastern Religion". The serious student of the history of science and medicine in East Asia should evaluate this literature with the same level of criticism as any other scholarly work, that is, based on its documentation ane argumentation.

A history of Chinese civilization which has more than the usual focus on the history of ideas and events in history of science, medicine and technology is the comprehensive survey by Jacques Gernet, *A History of Chinese Civilization*, Second Edition, Cambridge University Press, 1996. The major reference source in the study of history of science in China is the massive series compiled under the leadership of Joseph Needham, *Science and Civilization in China*, Cambridge University Press, 1954- . This multi-volume work, still in progress, is organized into two introductory volumes followed by individual volumes devoted to specific scientific fields, e.g., mathematics, meteorology, botany, etc. Abridgements of some of these volumes, useful as classroom texts, have been prepared by Colin Ronan together with Joseph Needham under the title *The Shorter Science and Civilization in China*, Cambridge University Press, 1978 - . A recent collection of useful essays by contemporary scholars is: Morris F. Low, Editor, "Beyond Joseph Needham: Science, Technology, and Medicine in East and Southeast Asia," *Osiris*, 2nd Series, Vol. 13, 1998.

Current scholarship on the history of science in China is published in a wide variety of places, apparently depending on the scholarly affiliation of the author. Some work appears in journals devoted to Asian studies, some in those on history of science and medicine, and some in sources covering particular disciplines, e.g., philosophy, astronomy, mathematics, etc. One central source for this scholarship is the annual *Current Bibliography*, published by *Isis*, the journal of the History of Science Society. The only journal in English devoted to this field is *Chinese Science*, published by the International Society for the History of East Asian Science, Technology, and Medicine (ISHEASTM). The *Newsletter for the History of Chinese Science* is published by the Institute of History, Tsing Hua University, Hsinchu, Taiwan, and is in Chinese.

International meetings are organized periodically by the International Society for the History of East Asian Science, Technology, and Medicine. The address of the society is ISHEASTM/SIHSTMAO, Instituts d'Extrême-Orient, 52 rue du Cardinal Lemoine, 75231 Paris Cedex 05, France. A major center for scholarly research in this field is the Needham Research Institute, 8 Sylvester Road, Cambridge CB8 9AF, United Kingdom. The URL for the Needham Research Institute website is http://www.nri.org.uk/. The NRI publishes a periodic newsletter which is free upon application. An internet bulletin board on East Asian Science, moderated by Nathan Sivin at the University of Pennsylvania, can be contacted at listproc@ccat.sas.upenn.edu. A website devoted to history of Chinese Medicine is at http://www.albion.edu/history/chimed/.

DAY 1
ORIGINS OF CHINESE SCIENTIFIC THOUGHT - I: DAOISM, CONFUCIANISM AND BUDDHISM

Theme: Man and nature

The period known as the Eastern Zhou dynasty (771- ca 453 BCE), when the Zhou moved their capital from the Wei valley to Loyang in the east of China, was when the Chinese world view was beginning to take shape. In the following period of political fragmentation, known as the Warring States period (453- ca 221 BCE), the major schools of Chinese thought were developed and refined. Confucianism, Taoism, Legalism and Moism all had their origins in this period. Buddhism, an important strain of Chinese thought, was a later import from India (1st-3rd c. CE). The aims of each of these schools of thought was to understand man's relationship to nature and to other human beings. Thus, theories of man as a social and moral entity and man as part of the universe were developed. To understand the background to later refinements of Chinese views of nature, it is important to have in mind the basic assumptions and world-views upon which these later ideas were predicated. Key concepts include the emphasis on relational aspects of the world, the notion of a parallelism between the earthly realm and a heavenly realm, and many forms of correlational thinking leading to elaborate theories of correspondences. In addition to general background reading in the cultural history of this period (e.g., Gernet, Chaps. 1-5), a selection

from one of the three great Confucian thinkers, Hsün Tzu (fl. 298-238 CE) illustrates a strongly realistic view of nature which attempts to channel the Confucian tradition into less superstitious and more rational directions. From this selection one can see Hsün's own rationalist position as well as something of the prevalent ideas of his time against which he was arguing.

Student Reading

- "Rationalism and realism in Hsün Tzu," in DeBary, Chan and Watson, *Sources of Chinese Tradition* (New York: Columbia University Press, 1960), pp. 112-127.
- Ronan and Needham, *The Shorter Science and Civilization in China*, Vol. 1 (Cambridge: Cambridge University Press, 1978), Chapters 4-5 (pp. 19-57).

Extended Reading

- J. Gernet, *A History of Chinese Civilization*, Second Edition (Cambridge: Cambridge University Press, 1996), Chapters 1-5, pp. 37-128.

DAY 2

ORIGINS OF CHINESE SCIENTIFIC THOUGHT - II: THE *HUAI NAN TZU*

Theme: A description of the Chinese world

The Huai nan tzu is one of the earliest texts which deals in a comprehensive and consistent way to formulate a view of what we would call nature. It is known in various editions and has been extensively studied and commented on by scholars in China since its composition in about 139 BCE. Unfortunately, it is not available in a complete translation in English even now. Recently, two scholarly translations of selected chapters have appeared, and we will read the introduction to the Huai nan tzu from Le Blanc's book. We will also read selections from the Huai nan tzu translated by an eminent Western scholar which illustrates the detail in which Chinese thought considered cosmological questions, and the complexity of a modern critical translation of an ancient text.

The Huai nan tzu has 21 chapters as follows (from Le Blanc):

1. Searching out Tao
2. The Beginning of Reality
3. The Patterns of Heaven
4. The Forms of Earth
5. The Seasonal Regulations
6. Peering into the Obscure
7. The Seminal Breath and Spirit
8. The Fundamental Norm
9. The Craft of the Ruler
10. On Erroneous Designations
11. Placing Customs on a Par
12. The Responses of Tao
13. A Compendious Essay
14. An Explanatory Discourse

15. On Military Strategy
16. Discourse on Mountains
17. Discourse on Forests
18. In the World of Man
19. The Necessity of Training
20. The Grand Reunion
21. Outline of the Essentials

The translation by John S. Major, published in 1993, is a detailed translation and critical study of only Chapters 3, 4 and 5. Major's translation of Chapter 3 (which he translates as "The Treatise on the Patterns of Heaven") includes detailed description of general cosmological notions, as well as astronomical observations and theories for each planet

Student Reading

Primary Text:

- Selections from the *Huai nan tzu* (ca. 139 BCE), in J.S. Major, *Heaven and Earth in Early Han Thought* (SUNY Press, 1993), pp. 62-75.

Background Reading:

- Charles Le Blanc, "*Huai Nan Tzu*" (Hong Kong University Press, 1985), pp. 1-8.
- "The Universal Order," in DeBary, Chan and Watson, *Sources of Chinese Tradition* (New York: Columbia University Press, 1961), Chapter XI.

Extended Reading

- Ronan and Needham, *The Shorter Science and Civilization in China*, Vol. 1 (Cambridge: Cambridge University Press, 1978), Chapters 7-11 (pp. 78-215).

DAY 3

ALCHEMY: THE NEI P'IEN OF GE HONG

Theme: Medicine, belief and alchemy

Medicine, alchemy, botany and the like are modern categories which do not alway correspond very well to the patterns of thought, writing and activity in past times. This holds for both East and West, of course. The treatise *Nei p'ien* by the 4th-century scholar, Ge Hong (Ko Hung), brings together ideas, theories, processes, and aims that we associate with both chemistry and medicine. It is also rooted in the cosmology of his time. A major interest of Chinese scholars for many centuries was the search for ways to attain immortality. Certain beliefs (especially of daoist origin) led to the idea that physical immortality was naturally possible. The search for understanding of this phenomenon involved many things we class under the rubric of chemistry, alchemy or even medicine. Because of the search for "elixirs of immortality" there were famous cases of failure with poisonings. The Ware translation of the *Nei p'ien* is the only one widely available, but it is heavily contaminated throughout with Western categories, assumptions and terminology. Reading it with an eye on these sorts

of problems can be a useful exercise. The basic ideas, however, give some sense of the medieval Chinese view of this aspect of nature.

Student Reading

- Ge Hong (Ko Hung), *Nei p'ien*, Chap. 4: "Gold and Cinnabar" and Chap. 11: "The Genie's Pharmacopoeia," in J.R. Ware, *Alchemy, Medicine and Religion in the China of A.D. 320: The Nei P'ien of Ko Hung (*Dover, 1981).

Extended Reading

- J. Needham and Ho Ping-yü, "Elixir Poisoning in Medieval China," in J. Needham, *Clerks and Craftsmen in China and the West* (Cambridge: Cambridge University Press, 1970), Chapter 16.

DAY 4
BEN CAO (PEN TS'AO) TRADITIONS

Theme: Natural history and materia medica in China

Two of the most important texts in Chinese medicine are *Huang di nei jing*, and *Ben cao gang mu* ("The Yellow Emperor's Classic of Internal Medicine" and "The Great Pharmacopoeia"). These texts are still used as the bases for Chinese Traditional Medicine. The *Huang di nei jing* is (probably) a multi-authored text in which a dialog between the mythical Yellow Emperor and one of his chief ministers explores many aspects of medicine: the concept of the body and its function, the detection, causes and treatment of illness, and the way remedies act. The *Ben cao gang mu* is a compendium of medication (in the broad sense) which gives the historical background for the drugs, much botanical information, as well as the indications for the uses of the materials. The literary tradition of such treatises on drugs gives a good idea of thinking about those areas now identified as botany, geology and mineralogy, as well as pharmacology and physiology.

Student Reading

Primary Texts:

- Selection on "Substance Therapies" in P.U. Unschuld. *Huang Di nei jing su wen : nature, knowledge, imagery in an ancient Chinese medical text, with an appendix, The doctrine of the five periods and six qi in the Huang Di nei jing su wen* (University of California Press, 2003), pp. 284-313.
- Li Shi zhen: *Ben cao gang mu* (1596), in P.U. Unschuld, *Medicine in China: A History of Pharmaceutics* (University of California Press, 1986), pp. 145-168.

Background Reading

- P.U. Unschuld, *Medicine in China: A History of Pharmaceutics* (University of California Press, 1986), pp. 11-28.

Extended Reading

- "Unification of the Empire, Confucianism, and the Medicine of Systematic Correspondences," in P.U. Unschuld, *Medicine in China: A History of Ideas* (University of California Press, 1985), Chapter 3.

DAY 5
EAST-WEST INTERACTIONS
Theme: Unity and diversity

Contrary to the view of many Americans, China, and Asia in general, has not been isolated from the rest of the world. During several periods in Chinese history government policies were expansionistic and embassies to distant foreign lands were dispatched. Chinese ships ventured widely and trade routes flourished between China and Europe. These interactions were sometimes interrupted for long periods, but there is much evidence to suggest substantial cultural and technical interchange. These suggested readings provide a general idea about such East-West interactions (Needham) and give two specific cases of such contact during the Tang (618-ca 900 CE) (Schafer), and the Ming (1368-1644 CE) (Spence).

Student Reading

- "The Glory of T'ang," in E. H. Schafer, *The Golden Peaches of Samarkand; a Study of T'ang Exotics* (University of California Press, 1963), Chapter 1.

- "Shall and Verbiest: To God Through the Stars," in J. Spence, *To Change China: Western Advisers in China, 1620-1960* (Penguin, 1980), Chapter 1.

Extended Reading

- "Conditions of travel of scientific ideas and techniques between China and Europe," in J. Needham, *Science and Civilization in China*, Volume 1 (Cambridge University Press, 1954), Chapter 7.
- Benjamin A. Elman, *A Cultural History of Modern Science in China* (Harvard University Press, 2006).
- Volker G. Scheid, *Chinese Medicine in Contemporary China: Plurality and Synthesis* (Duke University Press, 2002).
- Nathan Sivin, "A Cornucopia of Reference Works for the History of Chinese Medicine," *Chinese Science,* 9 (1989): 29-52.

DAY 6
SCIENCE IN CONTEMPORARY CHINA
Theme: Scientism, Marxism, Genetics and Bombs

Beginning in the late 19th century, reformers in China increasingly looked to Western learning to help China solve both internal and external problems. One aspect of such Western thought was Marxism. Another was Science. The two were somewhat related, since Marxism claimed to be a "scientific" approach to the world. The last century in China has seen a major struggle between traditional views of man, society and nature and some Western views of these things. Reformers in new Republican China initiated a major debate in the early 1920's about the "proper" philosophy for China. Belief in "Science" was a keystone of the reformers position. The victory of "scientism" in this struggle for the hearts and minds of the Chinese was a major factor in Chinese thought in this century. The other major influence was the Sinicised version of Marxism as developed by Mao and his followers. The politics of the Cold War were played out in such sensitive scientific fields such as genetics and atomic physics. The two suggested readings serve to illustrate the interplay of science, politics and ideology in the 20th-century Chinese context.

Student Reading

- L. Schneider: *Lysenkoism in China: Proceedings of the 1956 Qingdao Genetics Symposium* (M.E. Sharpe, 1986), pp. 1-9, 77-89.
- J. Huxley, *Heredity East and West: Lysenkoism and World Science* (Henry Schumann, 1949), pp. 1-34.
- J.W. Lewis and Xue Litai, *China Builds the Bomb* (Stanford University Press, 1988), Chapters 1-4.

Extended Reading

- D.W.Y. Kwok, *Scientism in Chinese Thought, 1900-1950* (Yale University Press, 1971), Chapter 1.

Possible Topics for Student Research

1. The nature of "proof" in Chinese mathematics
2. History of mechanical calculating aids
3. Chinese cosmology in art, literature, religion
4. Chinese conception of time and timekeeping devices
5. Natural history as art in the East and West
6. Genetics and crop breeding in early China
7. East-West exchange of natural products, plants and animals
8. Historical role of the *Nei Ching* in Chinese medicine
9. Comparison of the search for elixirs of immortality, East and West
10. Western medicine in China in the 20th C.
11. The role of the physician in Chinese society
12. Physics, cosmology, and Chinese music
13. History of ethanol in China
14. History of navigational theory practice in China

15. Epidemic disease in China and societal responses
16. Medicine, physicians and healing as portrayed in Chinese literature
17. Forensic science in China
18. Cross-cultural comparison of some particular concept about nature
19. Calendrical science in China
20. Books of historical importance in Chinese medicine

INDIA

Bill Johnson

INTRODUCTION

A study of the scientific achievements that have taken place on the Indian subcontinent will certainly surprise and perhaps entertain most persons. Surprised by the relevance of scientific discovery by Hindu, Islamic, and Buddhist philosophers to their everyday lives, they sometimes raise their eyebrows as they learn about the unique ideas that developed in a dynamic culture with many languages and religious points of view. Many scientific discoveries attributed to European origin actually came from India via Arab translators. Other ideas, such as how to prevent some plant diseases with boiled milk, had little influence on scientific thought beyond the local region, yet they are unique and quite interesting.

A vast number of individuals have contributed to the rich scientific heritage of India. People like Alberuni, though an Arab, worked extensively in India to introduce a new paradigm of experimentation to scientific investigation during the Middle Ages in his relentless pursuit of truth. Modern researchers like C.V. Raman, who won the Noble Prize for his work in physics in the 1920s, established India as a respected international player in a highly competitive research environment. In a society where science and culture are so intimately woven together, politicians such as Jawaharal Nehru played a significant role in the establishment of educational and governmental programs and institutions that have given science a place of respected priority among a people with a long tradition of scientific inquiry.

Topics are not arranged chronologically. Rather, we begin with an introduction to the human side of science: scientists. From there we consider modern scientific issues. With a contemporary perspective in place, we examine the historical foundation and developments occurring from ancient through Medieval times to give us a sense of appreciation for the significant place held by India's scientific tradition. A key topical focus is presented for each class. The readings reinforce or challenge this focus.

A secondary aim in the organization of this chapter is to strengthen the student's ability to conduct independent, original research.

Resources

- *Bharati ki Chaap* is a Hindi TV serial in thirteen 50-minute programs on five videocassettes, devoted to the history and development of science and technology in the subcontinent. It is in Hindi with English subtitles (published by South and Southeast Asia Video Archives of Madison, Wisconsin, in 1992).
- David Pingree, *Census of the Exact Sciences in Sanskrit* (series A & B) (Philadelphia: American Philosophical Society, 1970).

- Sachchidananda Bhattacharya, *A Dictionary of Indian History* (New York: George Braziller, 1967).
- *History of Science and Technology in India*. (12 volumes: v.1 health and medicine, science and religion; v.2 mathematics, astronomy; v.3 technology; v.4 science; v.5 science and technology; v.6 metals and metal technology; v.7 industries; v.8 coins, metallurgy; v.9 building construction; v.10 irrigation; v.11 geology; v. 12 environment and ecology) (Delhi: Sundeep Prakashan, 1990).
- Shailendra Kumar, *History of Science in India: Analytical Database of Information Sources* (New Delhi: Gyan Publishing House, 1994).
- *Symposium on the History of Sciences in India* held in Calcutta, 1961 (New Delhi: National Institute of Sciences of India, 1963).
- A. Rahman, *Trimurti Science, Technology & Society: A Collection of Essays (*New Delhi: People's Publishing House, 1972).
- Kapil Raj, *Relocating Modern Science* (Palgrave Macmillan, 2007).
- Arun Bala, *The Dialogue of Civilizations in the Birth of Modern Science* (Palgrave Macmillan, 2006).

Getting started with such a huge topic is challenging in and of itself. One must of necessity leave out a great deal in order to avoid a serious problem with information overload. My suggestions for getting started with developing a good working knowledge of the history of science in India will not find universal agreement among those interested in the topic, yet I have found these few sources to be extremely helpful, generally available, and sufficiently thorough.

Beginning with G. Venkataraman's *Journey Into Light: Life and Science of C.V. Raman* (Day 1), one is able to get a quick grasp of the modern issues facing Indian scientists. Familiarity with important personalities puts the subject into perspective and forms a solid basis for further study. The book is written in such a way that if you are interested in developing an understanding of the science involved, you may do so but you are not compelled to, if your main interest is in the people, places, and politics of modern Indian science. This work is valuable in making us appreciate the way scientific information was disseminated prior to the advent of electronic networks that span the globe. The race for priority documentation was intense, yet the quality of communication describing the research performed was not sacrificed.

Another work with which to acquaint yourself at the outset would be *Trimurti: Science, Technology, and Society*, a collection of essays by A. Rahman. The relationship between culture and scientific progress has been particularly strong in India and extensively researched. This particular contribution to the field introduces the political and educational issues with clarity. The future outlook and historical context is also presented in light of the unique challenges faced by developing countries in a rapidly changing technological culture.

Two works of broad interest include the twelve volume set *History of Science and Technology in India* and the *Proceedings of the Symposium on the History of Sciences in India* held in Calcutta in 1961. Both works provide an extensive review and survey of the literature though the former was published nearly 30 years after the symposium took place. Each provides quick access to a wide range of interesting topics by a wide variety of scholars.

Finally, Shailendra Kumar's work, *History of Science in India: Analytical Database of Information Sources* provides a fascinating collection of resources, people, and insight into the historiography of Indian science. This is an excellent source for becoming familiar with the research literature in the field and those who publish in these journals. Though many will not profit from the bibliometric analysis of the vast body of literature on the history of Indian science due to a lack of interest in this subject, all will appreciate this handy reference tool with its indexes by keyword, journal title, article title, and author. The numerous tables and charts clearly illustrate trends in the study of the history of Indian science, primarily since the formation of the Asiatic Society of Bengal in 1784.

For a list of biographical references, see **Day 1**.

The following libraries are known for their significant collections of South Asian materials. Print or electronic sources can establish network connections for searching these libraries via a WWW, Gopher, or Telnet connection:

- Cambridge University
- Center for Research Libraries (CRL), Chicago
- Cleveland Public Library
- Columbia University
- Cornell University
- Harvard University
- Library of Congress
- New York Public Library
- Oxford University
- University of California, Berkeley
- University of Chicago
- University of Hawaii
- University of Minnesota
- University of Pennsylvania
- University of Texas at Austin
- University of Toronto
- University of Washington

Major Journals

- Biographical Memoirs of Fellows: National Institute of Sciences of India
- Fellows of the Indian National Science Academy: Biographical Notes
- Harvard Journal of Asiatic Studies
- Indian Journal of Physics
- Indian Journal of Technology
- Indian National Science Academy Year Book
- Indian Science Cruiser
- Journal of the Asiatic Society of Bombay
- Journal of the Asiatic Society of Calcutta
- Journal of the Indian Institute of Science
- Proceedings of the Indian Academy of Science
- Proceedings of the Indian National Science Academy
- Proceedings of the Indian Science Congress Association

Electronic Resources

You may like to examine the Asian Studies Information Server on the World Wide Web at the following URL:

- http://coombs.anu.edu.au/WWWVL-AsianStudies.html.

The History of Science link on the World Wide Web Virtual Library is also very good, though broader in scope:

- http://coombs.anu.edu.au/SpecialProj/ASAP/WWWVL-HSTM.html.

DAY 1

Modern Men and Women of Indian Science: Key Personalities and Significant Achievements

Science happens when people seek to discover and learn about the world and their place in that world. These people formulate theories, test hypotheses, examine issues, manipulate experiments, and eventually apply the knowledge gained to improve life. Regardless of the type of system explored: physical, chemical, or biological, the work and the thoughts are accomplished at the hands and in the minds of people, both individually and in teams. In order to gain a sound appreciation and respect for the achievements of Indian science, one needs an introduction to the people who made it happen across the pages of history. People are the priority of science both to carry it out and to benefit from its occurrence.

The key topical concepts are that of "brain drain" and "scientific temper". In a country as culturally diverse as India, there must be a mechanism in place to maintain its intellectual and scientific integrity for 5000 years in the face of sudden invasion and the slow march of time.

Hindu philosophy is dominant in India and is capable of assimilating new ideas while remaining true to itself. Modern researchers have tackled a wide variety of theoretical and practical problems in all fields of inquiry. The struggle for political independence, however, has taken its toll on scientific achievement such that only one man in India has received a Nobel Prize for scientific research in this century.

A vast number of ancient theorists as well as modern experimentalists, from Hindu and non-Hindu belief systems, have made significant contributions to India's scientific tradition. While they are unique individuals, consider how their science has been woven together in a tapestry of Hindu assimilation.

Student Reading

- G. Ventataraman, *Journey into Light: Life and Science of C.V. Raman* (Bangalore: Indian Academy of Sciences, 1988), Chapters 1-3, 5, 12, 14.
- Pushpa M. Bhargava and Chandana Chakrabarti, "*Of India, Indians, and Science*," *Daedalus* 118(4), fall 1989: 353-368.

Extended Reading

- George Greenstein, "A Gentleman of the Old School, Homi Bhabha and the Development of Science in India," *The American Scholar* 61(3), summer 1992: 409-419.

- V.V. Krishna, "A Portrait of the Scientific Community in India: Historical Growth and Contemporary Problems," In *Scientific Communities in the Developing World*, Jacques Gaillard, V.V. Krishna, and Roland Waast (eds.) (New Delhi: Sage Publications, 1997).

Further Resources

- C.E. Buckland, *Dictionary of Indian Biography* (New York: Haskell House, 1968).
- *Fellows of the Indian National Science Academy, 1935-1993: Biographical Notes* (New Delhi: Indian National Science Academy, 1994).
- *Indian Scientists: Biographical Sketches with an Account of their Researches, Discoveries and Inventions* (Madras: G.A. Natesan & Co., 1929).
- Nem Kumar Jain, *Science and Scientists in India; Vedic to Modern* (Delhi: Indian Book Gallery, 1982).
- H. Kothari (ed.), *Who's Who in Indian Science* (Calcutta: Kothari Publications, 1969).

Possible Topics for Student Research

1. Describe "scientific temper" in its Indian context.
2. How does Indian culture and religion foster or hinder scientific inquiry?
3. Summarize the life and work of India's only Nobel Prize winner in science.
4. C.V. Raman's discovery could be described as a race against another research team. Which country did this other team represent and how did C.V. Raman win?
5. What role did Homi Bhabha play in the development of nuclear power in India?
6. Though not a scientist, what contribution to Indian science did Jawaharal Nehru make?
7. Botanist J.C. Bose proved that plants have life. True or False? Much of the equipment he used in his work was specially designed for him. Who was the designer and was it a common practice to use such design methods?
8. P.C. Ray had difficulty finding a university appointment in India after completing his doctoral work in chemistry in England. Why?
9. How did the development of special Indian research groups foster the creation of a local scientific community?
10. What is "brain drain" and what measures were taken in India to prevent it?

DAY 2
Modern Science in India: Relevant Issues and Concerns from Colonial Rule to the Present

Some of the best science occurs under the most challenging circumstances when a people determine to overcome the odds and make a difference. Economic and resource limitations, political inefficiency, cultural and religious diversity, language barriers, and educational reforms are some of the significant factors influencing the development of modern Indian science.

The key topical concept in this section is the role of science in culture and the influence of culture on scientific development. How did politics, education, and culture work to advance and retard science as India struggled for independence in the middle of the 20th century?

Student Reading

- S.N. Sen, "Factors in the Development of Scientific Research in India Between 1906 and 1930," *Indian Journal of the History of Science* 27(4) (1992): 379-387.
- Gyan Prakash, "Science 'Gone Native' in Colonial India," *Representations* 40 (fall 1992): 153-178.
- C.N.R. Rao and H.Y. Mohan Ram (eds.), *Science in India: 50 Years of the Academy* (New Delhi: Indian National Science Academy, 1985), pp. 1-50.

Extended Reading

- B.M. Johri (ed.), *Botany in India: History and Progress* (2 volumes) (Lebanon, NH: Science Publishers, 1995).
- J.N. Kapur, "Development of Mathematical Sciences in India During the Twentieth Century," *Indian Journal of History of Science*, 27(4) (1992): 389-408.
- A.S. Divatia, "History of Accelerators in India," *Indian Journal of Physics A* 62A(7) (October 1988): 748-774.
- Edward W. Ellsworth, "Indian Botanic Gardens," in *Science and Social Science Research in British India 1780-1880: The Role of Anglo-Indian Associations and Government* (*Contributions in Comparative Colonial Studies,* No. 28) (New York: Greenwood Press, 1991), pp. 115-131.
- Mel Gorman, "Introduction of Western Science into Colonial India: Role of the Calcutta Medical College," *Proceedings of the American Philosophical Society* 132(3) (1988): 276-298.
- Dhruv Raina and Irfan Habib, *Domesticating Modern Science: A Social History of Science and Culture in Colonial India* (New Delhi: Tulika Books , 2004).

Possible Topics for Student Research

1. What influence did the caste system have on the development of modern Indian science?
2. Identify at least three factors in the development of scientific research in India and discuss their relative merit.
3. Identify two governmental agencies established in the twentieth century to foster scientific research in India. Have they been effective? Why or why not?
4. How were the agencies identified in #3 started? What was their political basis of support and who were the key players in their establishment?
5. Identify two research institutes established in the twentieth century in India and describe their effectiveness.
6. How were the research institutes identified in #5 started. What was the economic basis for their establishment and what opposition did they face?
7. Identify two learned societies that were established in the twentieth century in India and discuss the motivation for their establishment.
8. Identify two scholarly publications that began in India in the twentieth century.
9. Cite examples of scientific mentoring in India.
10. How would you define colonial science?

11. Describe the shift from science as avocation to science as enterprise in India during colonial times.

DAY 3
Ancient Indian Philosophy: The Foundation of Science

Generally speaking, ancient Indians who theorized about scientific principles formulated a number of logical, abstract systems to explain the observed phenomena of natural processes. They developed two doctrines of elements. The Samhya, Nyaya, and Vaisesika schools proposed five fundamental elements while the Jaina, Buddha, and Carvaka schools, like the Greeks, proposed that there were four basic elements that constituted matter. Much thought was also given to the attributes of these elements.

The key topical concept is this Doctrine of Elements and a consideration of whether or not it was the Greeks or Hindus who first proposed that four basic elements formed all material substances. Who influenced whom and is it significant? What were the material attributes associated with these elements and are there modern theoretical counterparts to such substances as akasa?

Student Reading

- D.M. Bose (ed.), *A Concise History of Science in India* (New Delhi: Indian National Science Academy, 1971), pp. 1-50.
- B.V. Subbarayappa, "Glimpses of Science and Technology in Ancient and Medieval India," *Endeavour New Series* 6(4) (1982): 177-182.

Extended Reading

- Debiprasad Chattopadhyaya, *History of Science and Technology in Ancient India – The Beginnings* (Calcutta: Firma K.L. Mukhopadhyaya, 1986).
- Debiprasad Chattopadhyaya (ed.), *Natural Science of the Ancient Hindus*, (ICPR series in Philosophy of Natural and Social Sciences #2) (New Delhi: Indian Council of Philosophical Research, 1987).
- Allen, *Phonetics in Ancient India* (London: Oxford University Press, 1953).
- Raja Ramanna, *Sanskrit and Science* (Bombay: Bharatiya Vidya Bhavan, 1984).
- A.K. Bag, *Science and Civilization* (New Delhi: Navrang, 1985).
- A. Rahman (ed.), *Science and Technology in Indian Culture: A Historical Perspective* (New Delhi: National Institute of Science, Technology and Development Studies, 1984).

Possible Topics for Student Research

1. Discuss the application of mathematical knowledge in ancient India. Were the priests also mathematicians or did they rely on another class of technicians?
2. Describe the origin of our decimal system by the Hindus and how it was transmitted to Western culture.
3. How was health and disease defined in ancient India?

4. Three constituents formed the body according to ancient Indian doctors. What were they and what did each control?
5. Define normal and abnormal speech.
6. By what process is voice produced?
7. To what causes were speech disorders attributed?
8. How were speech disorders treated?
9. List the elements and their properties based on the theory of four fundamental elements.
10. What additional element was found in the theory of five fundamental elements?
11. Are there modern theoretical counterparts to the substance akasa?

DAY 4
Ancient Indian Science Applied

Once a theoretical framework had been established, the application of scientific principles could be applied to daily life through agriculture, engineering, and medicine. Specialization could also take place in such fields as astronomy, biology, chemistry, mathematics, and physics.

The key topical concept is that of atoms. How did substances behave at the atomic level? What were dyads and triads? Each "moment" in the life of atoms was important. Could you describe what the ancients believed took place in an atomic moment?

Student Reading

- D.M. Bose (ed.), *A Concise History of Science in India (*New Delhi: Indian National Science Academy, 1971), pp. 50-100.

Extended Reading

- B.L. Raina, *Health Sciences in Ancient India* (New Delhi: Commonwealth Publishers, 1990).
- John Bentley, *A Historical View of the Hindu Astronomy: The Earliest Dawn of that Science in India to the Present Times* (New Delhi: Cosmo Publications, 1981).
- Saradha Srinivasan, *Mensuration in Ancient India* (Delhi: Ajanta Publications, 1979).
- Brajendranath Seal, *The Positive Sciences of the Ancient Hindus* (London: Longmans, Green and Co., 1915).
- Jurgen Thorwald, *Science and Secrets of Early Medicine: Egypt, Mesopotamia, India, China, Mexico, Peru*, Richard and Clara Winston, (trans.) (New York: Harcourt, Brace & World, 1963).
- Debiprasad Chattopadhyaya, *Science and Society in Ancient India* (Calcutta: Research India Publications, 1977).
- "Science of Botany in Ancient India", *Studies in the History of Science in India*, vol. 1, Debiprasad Chattopadhyaya (ed.) (New Delhi: Editorial Enterprises, 1982), pp. 366-381.

- S.P. Raychaudhuri, "Some Aspects of Agricultural Practices in Ancient India (3250 B.C. - 800 A.D.)," in *Bulletin of the National Institute of Sciences of India* (Proceedings of the Symposium on the History of Sciences in India held at Calcutta on August 4-5, 1961) (New Delhi: National Institute of Sciences of India, 1963).

Possible Topics for Student Research

1. What were the attributes of atoms according to ancient Indian philosophers?
2. Were atoms considered material objects or an energy force?
3. Describe the changes that occurred through a series of atomic moments when an object such as a clay pot was heated.
4. Describe the basis for early medical practitioners accepting the notion of an organic sap of life.
5. What principles were involved with the idea of unity between nature and humans in ancient Indian medicine?
6. How were physics and meteorology relevant to therapeutics in the medical practices and theories of ancient India?
7. What evidence is there to suggest that rational medical treatment was more likely to be found with adherents to Buddhism rather than Hinduism?
8. Soils and humans were similarly classified in ancient India. Why?
9. Describe the variety of irrigation practices in ancient India.
10. Describe the variety of fertilizing methods among ancient Indian farmers.
11. Describe some of the methods of treating plant diseases among ancient Indian farmers.

DAY 5
Medieval India: Science Maturing

The study of science in Medieval India, from the 8th to the 18th centuries, is met with many challenges, not the least of which is fixing a date for this period. Most historians begin the period with the advent of Muslim conquerors in India. Others date it from the 13th to the 18th centuries. Based upon generous and broad strokes across the historical canvas, the period is long, nearly 1000 years and characterized by great change.

The key topical concept is the beginning of experimentation. In order to further theory, it must be refined by testing and manipulation. This gradual shift in focus was accompanied by further refinements in mathematical accuracy and precision. Consider major paradigm shifts and what must be overcome to reach for and eventually accomplish the stuff that discoveries are made of.

Student Reading

- Edward C. Sachau (ed.), *Alberuni's India: An Account of the Religion, Philosophy, Literature, Geography, Chronology, Astronomy, Customs, Laws, and Astrology of India about A.D. 1030* (London: Kegan Paul, Trench, Trubner & Co., 1914), Chapters 1, 4, 15, 36, 54.

Extended Reading

- M.S. Khan, "Arabic and Persian Source Materials for the History of Science in Medieval India," *Islamic Culture* 62(2-3) (1988): 113-139.
- James Burgess, *The Chronology of Modern India, for Four Hundred Years from the Close of the Fifteenth Century A.D. 1494-1894* (Edinburgh: John Grant, 1913).
- O.P. Jaggi, *Medicine in Medieval India* (*History of Science, Technology and Medicine*, vol. 8) (Delhi: Atma Rham, 1986).
- A. Rahman, M.A. Alvi, S.A. Khan Ghori, and K.V. Samba Murthy, *Science and Technology in Mediaeval India – A Bibliography of Source Materials in Sanskrit, Arabic, and Persian* (Delhi: Indian National Science Academy, 1982).
- O.P. Jaggi, *Science and Technology in Medieval India* (*History of Science, Technology and Medicine*, vol. 7) (Delhi: Atma Ram, 1986).
- *The Science of Medicine and Psychological Concepts in Ancient & Medieval India* (New Delhi: S.K. Manchanda, 1974).

Possible Topics for Student Research

1. Under what circumstances did Alberuni study in India?
2. Alberuni studied extensively in India. What was his assessment of Indian science up to 1000 AD?
3. What significant achievement is accorded to one of India's more energetic mathematicians, Madhave Sangamagrama?
4. How were scientific traditions generally transmitted during this time and why?
5. What was the connection between astronomy or astrology and medicine during the thirteenth century?
6. Discuss some of the early experiments of Alberuni.
7. Describe how accuracy was improved in various mathematical calculations such as the value of π (pi).
8. Alberuni and some of his contemporaries calculated the specific gravity of several substances. Describe their methodology.
9. What did scientists in India understand about the relationship between motion and heat at this time?
10. Which scientist in India addressed the problem of the velocity of light?
11. What significance did experimentation assume at this time in the history of science in India?

DAY 6
Medieval India: Unique and Lasting Contributions

Many of the scientific accomplishments made in South Asia during the Medieval period have been credited elsewhere, yet it is with great interest that we turn to India for unexpected discoveries and scientific applications during the Medieval millennium. In fact, a number of unique scholarly exchanges took place across this region that facilitated the transfer of new and improved theories into what later became modern Europe and the Western world.

The key topical concepts are translation and collaboration. A number of important scholarly works were translated from Greek into an Indian dialect and vice versa during the Medieval period. This kind of collaboration facilitated an exchange of new ideas between India and surrounding regions.

Student Reading

- *Indo-Soviet Seminar on Scientific and Technological Exchanges between India and Soviet Central Asia in the Medieval Period* (Proceedings in Bombay India, November 7-12, 1981) (New Delhi: Indian National Science Academy, 1981), pp. 1-65.
- Irfan Habib, *Medieval Technology Exchanges between India and the Islamic World* (Aligarh: Viveka Publications, 1985), pp. 1-26.

Extended Reading

- M. Saber Khan, "India in Hispano-Arabic Literature: An Eleventh Century Hispano-Arabic Source for Ancient Indian Sciences and Culture" (Calcutta, 1975). Reprinted from P.N. Joshi and M.A. Nayeem (eds.), *Studies in the Foreign Relations of India from the Earliest Times to 1974* (Hyderabad, 1975), pp. 356-389.
- *Interaction between India and Central Asian Science and Technology in Medieval Times* (Vol. 1: *General Ideas & Methodology, Astronomy, Mathematics, and Physical Concepts*, and Vol. 2: *Medicine, Technology, Arts & Crafts, Architecture, and Music*) (New Delhi: Indian National Science Academy, 1990).
- Vijaya Deshpande, "Transmutation of Base-metals into Gold as Described in the Text Rasarnavakalpa and Its Comparison with the Parallel Chinese Methods," *Indian Journal of History of Science* 19(2) (1984): 186-192.

Possible Topics for Student Research

1. Increased sea trade during this period fostered considerable opportunities for exchange of science and technology. What navigational instruments were introduced at this time and how did they influence the Indian economy?
2. By what route were new plants from Latin America introduced into India?
3. List some of the advancements which were made with textiles at this time.
4. What were some of the more important architectural developments of the period?
5. How successful was bridge construction at this time?
6. Present some of the important works translated from Greek to Indian dialects during the period and discuss their long term impact.
7. Present some of the important works translated from Indian dialects into Greek during the period and discuss their long term impact.
8. Long standing scientific traditions were heavily questioned by a leading researcher in India at this time. Who pursued objective truth in India with unequaled vigor during the middle ages and what success did he have in establishing a new paradigm of scientific inquiry?
9. Discuss the more common encyclopedic works produced at this time in India.

10. Summarize the scientific exchange between India and China or central Asia (Russia).
11. What contributions did the Portuguese make in our understanding of Indian botany?

AFRICA

Gloria T. Emeagwali

(with assistance of Constance Hilliard)

INTRODUCTION

The history of the sciences in Africa is rich and diverse. In ancient northeast Africa, those regions such as Egypt, Nubia and Aksum that had evolved large, complex state systems, also supported a division of labor which allowed for the growth of science and the more practical technologies involved with the engineering of public works. In other parts of Africa, in the various city states, kingdoms, and empires that dominated the political landscape, science and technology also developed in various ways. The applied sciences of agronomy, metallurgy, engineering and textile production, as well as medicine, dominated the field of activity across Africa. So advanced was the culture of farming within West Africa, that 'New World' agricultural growth was spawned by the use of captives from these African societies that had already made enormous strides in the field of agronomy. In her work *Black Rice*, Judith Carnoy demonstrates the legacy of enslaved Africans to the Americas in the sphere of rice cultivation. We know also that a variety of African plants were adopted in Asia, including coffee, the oil palm, fonio or acha (digitaria exilis), African rice (oryza glabberima), and sorghum (sorghum bicolor). Plants, whether in terms of legumes, grain, vegetables, tubers, or, wild or cultivated fruits, also had medicinal implications for Africans and were used as anesthetics or pain killers, analgesics for the control of fever, antidotes to counter poisons, and anthelmints aimed at deworming. They were used also in cardiovascular, gastro-intestinal, and dermatological contexts. Some of these such as hoodia gordonii and combrettum caffrum are being integrated within contemporary pharmaceutical systems.

The African landscape is dotted with the remnants of walled enclosures of various dimensions in Southern Africa and West Africa. The irrigation terraces of Gwoza and Yil Ngas, Nigeria, and the earthworks of Benin are major testimonies to the engineering activities of ancient West Africans. The Benin earthworks have been estimated about 10,000 miles long by the archeologist Patrick Darling. The totality of all the irrigation terrace lines or contours in Gwoza, northeast Nigeria, may be on the order of 20,000 miles, according to researchers such as White and Gwimbe, who have done extensive work on this subject. Various architectural styles emerged in the region with a propensity for sun dried clay in the West African Sahelian region and East Africa. Obelisks, stelae, sphinxes, flat topped and peaked pyramids, walled enclosures called zimbabwes, sculptured temples, terraces and beehive, circular and rectangular dwellings, are among the wide variety of engineered structures of Africa.

After the 3rd century B.C.E., a process of cross-fertilization among the ancient Egyptians, Nubians, and Aksumites of Africa; their Mediterranean neighbors in Greece; and the Semitic peoples of Western Asia ushered in one of the most dynamic eras of scientific discovery the world has yet known. The Egyptian port city named after its Macedonian conqueror, Alexander the Great, became the locus of this extraordinary scientific energy. The Library of Alexandria, built apparently on an ancient Egyptian city, contained at its height well over a million books. While some European scholars of an earlier era categorized the remarkable scientific achievements emanating from Egypt during that period as essentially Greek, it is now apparent that the greatness of this epoch actually resulted from conjoining Northeast Africa's three thousand years of accumulated scientific knowledge with that of their ancient Greek conquerors. It has been suggested that Egypt's first significant scientific document, the so-called Edwin Smith Papyrus, was initially written 2500 years before the Greek conquest of Egypt in 332 B.C.E. Hellenized Egyptians like Claudius Ptolemaeus, Heron, and the female mathematician Hypatia helped lay the foundations for what later European scholars came to label the "Greek sciences." This may be in part because the educated Egyptians of that later era wrote in Greek or a derivative language of ancient Egyptian called Coptic, which employed the Greek alphabet.

The various papyri, most of which are named after non-Egyptian personalities and towns, ironically, are significant repositories of the ancient scientific knowledge of northeast Africa. The Edwin Smith papyrus remains a remarkable scientific treatise on surgery. Of the 48 cases described, 27 concern head injuries and 11 skull fractures. Some have posited that the classification of head wounds of Hippocrates, 460-377 B.C.E., derived from the Egyptian Edwin Smith papyrus. Egyptian medical papyri also include the Ebers Papyrus of 1500 B.C.E., devoted to cysts and boils—perhaps the first treatise on cardiology; and the Kahun and Carlsberg Papyri, primarily devoted to gynaecology, and dating back to 1820 B.C.E. and 1300 B.C.E., respectively. The Chester Beatty Papyrus of 1200 B.C.E. was primarily devoted to rectal ailments. In these various papyri, we have case titles, diagnoses and prescription, and presentation of data in an organized fashion. The reasoning used is largely inductive and experimental. From analyzing these documents, we know that their authors clearly recognized the effects on the lower limbs of brain injuries, attained familiarity with the nervous system, and indicated knowledge of the circulation of the blood. The ancient northeast Africans gave us the earliest known description of the brain.

Our word "chemistry" derives from "al-kemi." The ancient Egyptians had applied this term meaning "the black land" to themselves. We should note, however, that some contemporary scholars interpret "kemit" to refer to the dark richness of the Egyptian soil, while others suggest that the term "black" refers in this instance to the skin pigmentation of these ancient peoples. In various parts of Africa, chemical principles were applied— especially in the leather tanning and cloth dyeing sectors. Indigenous distillation systems emerged in the process of the brewing of beer and other fermented beverages in various regions of Africa.

Resources

For a general introduction to Africa and the scientific traditions of Africa, see:

- Molefi Asante, *The History of Africa* (NY: Routledge, 2007).
- Thomas Bass, *Camping with the Prince and Other Tales of Science in Africa* (Boston: Houghton Mifflin, 1990).
- Gloria Thomas-Emeagwali, (ed.), *African Systems of Science, Technology and Art* (London: Karnak, 1993).
- ---------------------*The Historical Development of Science and Technology in Nigeria* (Edwin Mellen, 1992).
- -------------------- *Challenging Hegemonic Discourses on Africa* (Trenton, NJ: Africa World Press, 2006).

Other supplementary texts can shed light on contemporary problems and developments. Their general focus is on non-traditional science and technology, and they therefore emphasize the variables, concepts, and criteria associated with conventional and mainstream science.

- *Science in Africa: Achievements and Prospects* (Washington, D.C.: AAAS, 1991).
- *Science in Africa: Women Leading from Strength to Strength* (Washington D.C.: AAAS, 1993).
- J.W. Forje, *Science and Technology in Africa* (London: Longman, 1989).
- *Science, Technology and Endogenous Development in Africa: Trends, Problems and Prospects* (UNESCO, 1987).
- Sal Restivo, (ed.), *Science, Technology and Society* (Oxford: OUP, 2005).
- Constance Hilliard, *The Intellectual Traditions of Africa* (McGraw Hill, 1997).
- Ivan Van Sertima, Blacks in Science (Rutgers, 1990)
- H. Selin, Encyclopedia of the History of Science and Medicine in Non-Western Science (Kluwer, 1997)

Many books published in Africa are available from: The African Books Collective, The Jam Factory, 27 Park End St., Oxford OX1 1HU, England; Fax: 0865-793298.

Journals , Newsletters and Web Sites

- *Indigenous Knowledge and Development Monitor* (The Hague, The Netherlands: CIRAN/Nuffic).
- *African Technology Forum* (Cambridge, MA: MIT Press).
- *AMUCHMA Newsletter* (Maputo, Mozambique: African Mathematical Union, Instituto Superior Pedagogico).
- www.africahistory.net: African Indigenous Knowledge Systems
- www.ccsu.edu/afstudy/archive.html, *Africa Update,* Newsletter of African Studies at Central Connecticut State University. There is a focus on indigenous chemistry, engineering and metallurgy in volume 15.

DAY 1
Astronomy, Physics and Mathematics

Africa's areas of scientific investigation include the fields of astronomy, physics, and mathematics. Laird Scranton, making use of the extensive collections of Marcel Griaule, has deepened our understanding of Malian cosmological myths and their perceptions of the structure of matter and the physical world. Dogon knowledge systems have also been explored in terms of their perceptions on astronomy. Dogon propositions about Sirius B have been discussed by Charles Finch in *The Star of Deep Beginnings.* The solar calendar that we use today evolved from the Egyptian calendar of twelve months, calibrated according to the day on which the star Sirius rose on the horizon with the Sun. Scranton suggests major interconnections between the thought of the ancient Egyptians and that of the Malians of West Africa.

In the field of mathematics, the ancient Egyptians engaged in geometric problem solving considerably before the arrival of the Greeks. They incorporated in their mathematical activity numerous mathematical principles, including the principle of progressive doubling, the concept of square root, and quadratic equations. Egyptian and Nubian builders calculated the volumes of masonry and building materials, as well as the slopes of pyramids, for construction purposes. Bianchi points to a Nubian engraving at Meroe, in ancient Sudan, dated to the first century B.C.E., which reflects "a sophisticated understanding of mathematics." Included in the engraving were several lines, inclined at a 72-degree angle, running diagonally from the base of a pyramid. Bianchi suggests that the Nubian King Amanikhabale of the first century BCE was the owner of that pyramid. Interestingly, the Nubians of Meroe, who constructed more pyramids than the Egyptians, built steep, flat-topped pyramids.

The history of mathematics in other parts of Africa has been examined by the African Mathematical Union, based in Mozambique, and other scholars. Hundreds of sources have been listed, including 20th-century works of anthropologists such as Delafosse (1928), Almeida (1947), Armstrong (1962), and Cheik Anta Diop. There are historically very practical explanations for the development of mathematics in the continent. A complex system of trade developed across the Sahara and with Asia, based on commodities such as gold and gold dust, kola nuts, leather items such as bags, and various types of textile. For African Muslims, the calculation of inheritance and the distribution of Zakat necessitated mathematical accuracy. Some indigenous systems of calculation were decimal (based on ten), while others were vigesimal, based on twenty, such as the Yoruba system. Distinctions were made between prime numbers and multiples that contained other numbers. Various symbols evolved to represent various quantities, fractions, etc. Much of what we know about African systems of logic is manifested in games of strategy such as mancala and ayo, games of alignment, and puzzles. The major sources for studying mathematics are archaeological relics, such as the Ishango Bone of the Congo with pattern of notches etched onto it, and oral tradition in the form of riddles, proverbs, and narratives. Paulus Gerdes has done a great deal of work analyzing sand drawings, as well as basketry, to decipher some of the underlying mathematical underpinnings. Ron Eglash has pointed out that traditional

African settlements as well as coiffure and hair braiding, tend to reflect fractal structures, in his words, 'circles of circles of circular dwellings, rectangular walls enclosing ever-smaller rectangles, and streets in which broad avenues branch down to tiny footpaths with striking geometric repetition.'

Student Reading

- Claudia Zaslavsky, *Africa Counts: Number and Pattern in African Culture* (Brooklyn: Lawrence Hill, 1979), Chapters 1-3.
- Sal Restivo, (ed.), *Science, Technology and Society* (Oxford: OUP, 2005).

Extended Reading

- Paulus Gerdes, *Explorations in Ethnomathematics and Ethnoscience in Mozambique* (Mozambique: Instituto Superior Pedagogico, 1994).
- Paulus Gerdes, *Sona Geometry from Angola – Mathematics of an African Tradition* (Monza, Italy: Poliometrica Scientific Publisher, 2006).
- *SIPATSI: Technology, Art and Geometry in Inhambane* (Mozambique: Instituto Superior Pedagogico, 1994).
- Richard Gillings, *Mathematics in the Time of the Pharoahs* (New York: Dover, 1982).
- Gay Robins and Charles Shute, *The Rhind Mathematical Papyrus: An Ancient Egyptian Text* (New York: Dover, 1987).
- Paulus Gerdes, "On Mathematics in the History of Sub-Saharan Africa." *Historia Mathematica*, *21* (1994): 345-76.
- J.W. Forje, *Science and Technology in Africa* (London: Longman, 1989).
- Robert Steven Bianchi, *Daily Life of the Nubians* (Westport, Connecticut, 2004).
- Laird Scranton, *The Science of the Dogon: Decoding The African Mystery Tradition* (Rochester, Vermont, 2006).
- Hellen Verran, *Science and an African Logic* (Chicago, University of Chicago Press, 2001).
- Charles Finch, *The Star of Deep Beginnings* (Georgia: Khenti, 1998).
- Ron Eglash, *African Fractals* (NJ: Rutgers University Press, 1999).
- Ron Eglash: African Fractals in buildings and braids (in video format), 2007: www. TED.com
- http://www.math.buffalo.edu/mad/Ancient-Africa/index.html Mathematicians of Africa and the African Diaspora.

DAY 2
Medicine

Some common patterns and trends in medicine emerged across the continent. These included scientifically proven methods, as well as techniques and strategies which were culturally specific and psychologically significant. Among the common principles and procedures were hydrotherapy, heat therapy, spinal manipulation, quarantine, bone-setting and surgery. Incantations and other psychotherapeutic devices sometimes accompanied other techniques. The knowledge of specific medicinal plants was quite extensive in some knigdoms,

empires, and city states such as Aksum, Pharaonic Egypt (in the Northeast), and Borgu (in Hausaland). The latter continues to be well known for orthopedics (bone-setting), as is the case of Funtua in Northern Nigeria. Many traditional techniques are still utilized in some areas. Others have undergone change over time, have been revived in more recent periods, or have fallen into oblivion.

In Northeast Africa, numerous documents were written in Geez, Amharic, and hieroglyphics. These contain thousands of prescriptions for a wide range of diseases. The Edwin Smith Papyrus is useful for the Pharaonic Egyptian era, as earlier discussed. Unfortunately, scholars have been unable to decipher the Nubian Meriotic script. Oral tradition in conjunction with texts written in Arabic constitute the main sources of information on West Africa. CICIBA of Gabon has produced several works (largely in French) on medicine in the Bantu-speaking regions of Central and Southern Africa.

Student Reading

- F.P.A. Oyedipe, "Science in the Metaphysical Aspects of Yoruba Traditional Medicine," in *African Systems of Science, Technology and Art*, G. Thomas-Emeagwali, (ed.) (London: Karnak, 1995), Chapter 5.
- Bassey Andah, *Nigeria's Indigenous Technology* (Ibadan, Nigeria: Ibadan University Press, 1992), Chapter 3.

Extended Reading

- Abayomi Sofowora, *Medicinal Plants and Traditional Medicine in Africa* (Ibadan, Nigeria: Spectrum/John Wiley, 1985).
- Keto Mshigeni, *Traditional Medicinal Plants* (Dar Es Salaam: Dar Es Sallam University, 1991).
- Z.A. Ademuwagun, *African Therapeutic Systems* (Los Angeles: Crossroads Press, 1979).
- Sandra Anderson and Frants Staugard, *Traditional Midwives* (Gaborone, Botswana: Ipelegeng Press, 1986).
- Cyril P. Bryan, (trans.), *Ancient Egyptian Medicine: The Papyrus Ebers* (Chicago: Ares Press, 1974).
- Pascal James Imperato, *African Folk Medicine: Practices and Beliefs of the Bambara and Other Peoples* (Baltimore: York Press, 1977).

DAY 3
Microbiology and Food Processing

Indigenous fermented foods in Africa have usually been derived from cassava tubers, cereal legumes, oil seeds, palm tree sap, milk, and various other local products. The scientific basis of indigenous food fermentation lies in the nature of the microorganisms involved in fermentation; the microbially induced changes of the base product; the nature of the enzymatic reactions which take place; and the specific nature of the end product in terms of nutritional and preservative qualities. A scientific process should be repeatable and open to scrutiny in such a way as to facilitate evaluation and perhaps further experimentation and research. Common to various parts of the continent are

dehydrated granular food products that involve fermentation, frying, and dejuicing, or products such as sorghum, maize, or other cereals that may be fermented and made into alcoholic beverages. Food processors became aware of the significance of the various agencies by virtue of trial and error experimentation. Metallic objects have sometimes been used to hasten fermentation and in this case serve as trace elements, thus promoting the growth of the relevant microorganisms.

African civilization may be associated with specific methods of preparing and even consuming food items in ways that tend to reflect some measure of uniformity throughout the continent. Fast food items ranging from couscous to "qari," or cassava granules, various types of cereal-based flour, pulverized tubers of various kinds, and a wide variety of vegetable-based soups all give African cuisine a distinct character. It must be stressed that food preparation involves hypothesis formulation, the assumption of regularity in nature, and a measure of logical and predictive capability on the part of the food processor or agent associated with food preparation.

This seems to be an under-researched issue, in need of collaborative work among historians and microbiologists, nutritionists, and sociologists. Some work in this area has been done by Richard Okagbue, formerly of the University of Zimbabwe. Sources of information for culinary trends include: excavated sites; motifs on sculpture, carvings, and textile; oral history narratives, proverbs, popular literature, poetry, and incantations; travel reports, such as that of Ibn Battuta; research in African/Carribean and African-American culinary patterns for example, revealing pervasive use of gumbo, black-eyed peas, and cowpeas- and indigenous writings in Arabic (for example, the *Abuja Chronicles*).

Student Reading

- Richard Okagbue, "Microbiology and Traditional Methods of Food Processing," in *The Historical Development of Science and Technology in Nigeria*, G. Thomas-Emeagwali, (ed.) (Edwin Mellen, 1992).
- Hamid Dirar, *The Indigenous Fermented Foods of the Sudan* (Wallingford, UK: CAB International, 1992).

Extended Reading

- Bassey Andah, *Nigeria's Indigenous Technology* (Ibadan, Nigeria: Ibadan University Press, 1992).
- Africa Update. Vol. X1V. Issue 4 (Fall 2007) – Nigerian Indigenous Chemistry (www.cdcsu.edu/afstudy/archive.html)
- Judith Carney, *Black Rice, The African Origins of Rice Cultivation in the Americas* (Cambridge, Mass., 2001).

DAY 4
Metallurgy

Various types of metal products have been used over time by Africans, ranging from gold, tin, silver, bronze, brass, and iron/steel. The Sudanic empires of West Africa emerged in the context of various commercial routes and activities involving the gold trade. In the North and East, Ethiopia and Sudan were the major suppliers of gold, with Egypt a major importer. In Southern Africa, the kingdom of Monomotapa (Munhumutapa) reigned supreme as a major gold producer. In the various spheres of metal production, specific techniques and scientific principles included: excavation and ore identification; separation of ore from non-ore bearing rock; smelting by the use of bellows and heated furnaces; and smithing and further refinement.

The use of multishaft and open-shaft systems facilitated circulation of air in intense heating processes, while the bellows principle produced strong currents of air in a chamber expanded to draw in or expel air through a valve. The various metal products served a wide range of purposes, including: armor (as in some northern Nigerian city-states), jewelry (of gold, silver, iron, copper and brass), cooking utensils, cloth dyeing, sculpture, and agricultural tools. The technical know-how and expertise of blacksmiths helped to enhance their status, although they were also often associated with supernatural and psychic powers, as well.

Student Reading

- Fred Anozie, "Metal Technology in Pre-colonial Nigeria," in *African Systems of Science, Technology and Art*, Gloria Thomas-Emeagwali, (ed.) (London: Karnak, 1993), Chapter 7.
- Bala Achi, "Engineering in Pre-colonial Nigeria: The Construction of Fortifications," in *African Systems of Science, Technology and Art*, Gloria Thomas-Emeagwali, (ed.) (London: Karnak, 1993), Chapter 9.

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- Bassey Andah, *Nigeria's Indigenous Technology* (Ibadan, Nigeria: Ibadan University Press, 1992).
- Peter R. Schmidt, *Iron Technology in East Africa: Symbolism, Science and Archaeology* (Bloomington: Indiana University Press, 1997).
- I. Van Sertima, *Blacks in Science* (NJ, Transaction Books, 1992).

Video

- *Tree of Iron* — shows steel making by the Bahaya of Tanzania.

DAY 5
Textile Manufacturing

Skill and expertise developed in various parts of the continent in terms of the making of yarn, weaving pit or pot dyeing and various activities associated with cloth-making. Over time evolved vertical and horizontal looms, vertical frames on which the beams were tied, supportive items for the cross-pieces or beaters and shedsticks, shuttles and other technical devices, and vegetable dyes of various colors. Women played a major role in this area of material culture, as in food processing. In textile production, product design and the invention of innovative techniques largely derived from females. In more recent times, with the introduction of capital intensive technology, women have been pushed aside, from some activities that they once dominated. Generally, the raw materials used in textile included camel hair, wool, flax, raffia palm, and cotton. Flax was commonly used in Egypt, while cotton from indigenous species and raffia palm were common to various parts of West, Central, and Southern Africa. Silk cloth was produced in Western and Central Nigeria, as well as other places, though less extensively. Some city-states and empires became famous for particular types of cloth and product design. Akwete, Ilorin, and Okenne, for example, gave their names to the cloth produced in their regions. Textile technology has not been static, and over time interacted with the prevailing value systems to facilitate communication. Ideas, emotions, attitudes, beliefs, and political philosophy were symbolized in specific ways by the use of a diverse range of motifs. Sotiba (Senegal), Kente (Ghana), Adinkra (Ivory Coast and Ghana), Sanyan, a silk based fabric made in western Nigeria, Adire (starch resist fabric) and Aso Olona, title cloths of the Ijebu, are some of the various types of indigenous African cloth. Knowledge about textiles spread from travel reports ,for example, Mungo Park in Ivory Coast, Cadamosta in Senegambia, Bailie in Nigeria and much earlier, Herodotus in Egypt. Missionary reports, autobiographies such as that of Equiano of Nigeria, archaeological sites such as Igbo-Ukwu, Nigeria or the 11th-century Bandiagara Cliffs in Mali, and oral tradition have been useful repositories of information on African textiles.

Student Reading

- *African Technology Forum*, Vol. 7, No. 2 (1994).

Extended Reading

- T. Picton and J. Mack, *African Textiles* (London: British Museum, 1991).
- J. Gillow, *African Textiles* (London, 2003).
- Olayemi Akinwumi, et al. *African Indigeneous Science and Knowledge Systems: Triumphs and Tribulations, Essays in Honor of Gloria Thomas Emeagwali* (Nigeria, Abuja: Roots Books and Journals, 2007).

DAY 6
Engineering and Building Technology

In various parts of ancient, medieval, and contemporary Africa, building constructions of various dimensions, shapes, and types emerged, reflecting various concepts, techniques, raw material preferences, and decorative principles. Builders integrated the concepts of the arch, the dome, and columns and aisles in their constructions. The underground vaults and passages, as well as the rock-hewn churches, of Axum are matched in Nubia and Egypt with pyramids of various dimensions. In the Sahelian region, adobe, or dried clay, was preferred in the context of moulded contours, at times integrated with overall moulded sculpture. Permanent scaffolding made of protruding planks characterized the Malian region. The principle of evaporative cooling was integrated into building design. Mats were used as part of the decor and also to be saturated repeatedly in order to cool the room.

Derelict ruins from walled cities—such as Kano, Zazzau, and other city-states of Hausaland in the central Sudanic region of West Africa—complement structures such as the rock-hewn and moulded churches of Lalibela in Ethiopia or the Zimbabwe enclosures. The structures of ancient Nubia, as well as those of Egypt, are parallel structures in the northeast. It is possible to see these ruins through various video productions now available. One may also find eyewitness accounts and sketches, such as those by Rene Caille and Henrich Barth.

Student Reading

- Bassey Andah, *Nigeria's Indigenous Technology* (Ibadan, Nigeria: Ibadan University Press, 1992).
- P.J Darling, *Archaeology and History in Southern Nigeria: The Ancient Linear Earthworks of Benin and Ishan* (Cambridge Monographs, 1990).
- *Africa Update*. Vol. XV. Issue 2 (Spring 2008) – African Engineering: Terraces and Earthworks (www.ccsu.edu/afstudy/archive.html)

Extended Reading

- Graham Connah, *African Civilisations* (Cambridge: Cambridge University Press, 2001).
- Webber Ndoro, "The Great Zimbabwe," *Scientific American*, 277 (Nov., 1997): 94-99.
- Peter Garlake, *Early Art and Architecture of Africa* (Clarendon: Oxford University Press, 2002).
- *Video: Tubali: Hausa Architecture of Northern Nigeria* (Ogbuide Corporation).

Possible Topics for Student Research

1. Agronomic techniques and new crops taken by West Africans to the Americas.
2. African crops such as the oil palm, coffee and sorghum and their impact on Asia.
3. Herbal medicines selected for treatment of illnesses in various African regions.
4. The holistic African model of illness and disease.
5. Traditional surgical procedures and techniques in various parts of Africa.
6. Engineering and architectural skills in the building of the Egyptian and Nubian pyramids.
7. Ethiopian sculptured temples such as the Lalibela Churches of the 13th century.
8. Regions of ancient West Africa which developed indigenous suspension bridges .
9. Comparison of the ancient architectural styles of West Africa with that of Southern Africa.
10. African irrigation terraces in any two regions of West Africa.
11. Elements of modern calendar derived from the Egyptian calendar.
12. African cosmological thought permeating the culture and religion of various city states, kingdoms and empires.
13. The naming of constellations by the Ancient Malians.
14. Techniques of counting and calculation in African societies.
15 The vigesimal system in Yoruba mathematics.
16. Indigenous metallurgy with respect to iron and steel in East Africa..
17. Role of women in the production of West African textiles such as *adire, sanyan, adinkra and kente.*
18. Food processing techniques and indigenous fermented beverages
19. Perceptions of time and space in various parts of Africa.
20. Five scientific works authored by 19th century scientists.
21. Interconnections between religion and science in West Africa.
22. Biographical notes on Nigerian scientists such as the mathematician Chike Obi.
23. Comparing the aggregate mileage in ancient West African terraces and earthworks.
24. Intellectual property rights and African indigenous practitioners.

Native America

Clara Sue Kidwell

INTRODUCTION

If a basic premise of science is that systematic observation of the world will reveal uniform patterns of events in the environment, then American Indians were very capable scientific practitioners. Physical aspects of the landscape became markers of the annual solstice points of the sun. The cycles of animal and plant life and the appearance of the moon divided the year into regular months. Native people managed their environments with fire and technologically sophisticated irrigation systems. They domesticated plants, developed agricultural systems that took advantage of complementary relationships among those plants, and were keenly aware of the effects of plants on the human body.

Knowledge about the environment is readily available to anyone who cares to observe, and in theory, everyone could be a scientist. If a second basic premise of science is that there are intellectual explanations for why the patterns of events in the environment exist, then obviously, not all people are scientists. Science in the Western European tradition is an elitist activity, and American Indian societies had their specialists who acquired, guarded, and passed on explanations of the natural world. These explanations have generally been dismissed as myth or folklore, certainly not acceptable science in a modern sense. Without written records, we must work backward from oral traditions preserved in contemporary written form and from physical remains to determine the purposes of ancient activities. What we can know is that Native people were keen observers and recorders of patterns in the actions of the natural environment, whether of stars, or animals, or plants. Those patterns served as predictors of events and allowed people to manage their physical resources in productive ways.

No single construct can be called Native American science. The commonality in the Western Hemisphere, however, can be described as a sense that the forces in the environment were powerful, sentient, and willful beings whose actions had profound impact on human life, but whose actions it was within the province of human beings to influence. By observing closely and noting patterns of activity in their environments, Indian people could exercise control over their resources.

The basic point at which Native practices diverge from contemporary science is in the practice of experimentation. Native people saw themselves in an ongoing relationship with the forces of the environment. They influenced them through their own activities in ceremonies. Human action was necessary to the continuation of natural cycles. Solstices were marked, but ceremonial activity was necessary for continuation of the sun's movement in its path across the sky. The Hopi would not have considered the possibility of not performing their ceremonies to see if the sun would, indeed, reverse its direction or not.

Skepticism had no place in the carefully balanced and maintained worlds of Native communities. A study of American Indian observational practices and systems of explanation can, however, introduce students to some basic ways of conceptualizing principles of present-day science.

Day 1
Astronomy

Astronomy is the prime example of an observational science. Everyone can observe the movements of the sun and moon and stars in the sky. Few people pay attention to the complex patterns of interaction among those bodies. Native observation of the sun, moon and stars produced significant physical records of patterns in their movement and intellectual achievement in discerning the predictive power of those patterns.

Although the most well-known systems are those of the Maya and Aztecs in Mesoamerica, many North American people created solstice markers, and some may have been aware of the rising points of certain bright stars or constellations that preceded solstices. The Pleiades were widely used to determine planting seasons for many agricultural tribes. As a winter constellation, their first appearance in the night sky in the fall marked the approximate date of the first killing frost, and their disappearance similarly marked the last.

The Medicine Wheel in the Big Horn mountains of Wyoming is a solstice marker constructed by hunting people who were probably ancestors of contemporary Shoshone people. For them, knowledge of the turning of seasons was crucial in predicting the movements of game animals. Medicine wheels are widespread on the northern plains, where they served as markers of seasonal changes.

For the Hopi in the Southwest, ceremonial cycles were (and in many cases still are) governed by observation of solstice points. The Hopi also, however, had a sophisticated knowledge of the relationship of movements of the moon to the sun. The Mayan calendar system, which probably derived from early Olmec culture and which was appropriated by the Aztecs along with much of the Mayan intellectual heritage, predicted eclipses of the moon and encompassed extended cyclical patterns in the heavens. The movements of the planet Venus were of particular interest.

The study of archaeoastronomy is fascinating for what it shows about the accumulation of knowledge over long periods of time. Although the pattern of movement of the sun along the horizon marked by the solstices can certainly be obvious within the span of a single human lifetime, lunar eclipses are much less frequent. Patterns in the motion of Venus are more complex. To discern them was probably the work of several lifetimes and the accumulation of evidence by a number of viewers. The hieroglyphic writing systems of Mayan and Aztec cultures could allow for such accumulation and recording of information, but other traditions in North America, such as those concerning the Pleiades, occurred among tribes that did not have written languages. The Pawnee Indians on the central Great Plains had an elaborate oral tradition about the morning star and the evening star as the progenitors of the human race. It was evidently

based on changing relationships in the positions of Venus, Mars, and Jupiter throughout the year.

Anthony Aveni's excellent introduction to astronomy with the naked eye can give students the skills they need to understand complex celestial phenomena and the process of systematic observation.

Student Reading

- Cesi, Lynn, "Watchers of the Pleiades: Ethnoastronomy Among Native Cultivators in Northeastern North America," *Ethnohistory*, XXV (4) (Fall, 1978): 301-317.
- Eddy, John A., "Astronomical Alignment of the Big Horn Medicine Wheel," *Science*, *174* (June 10, 1974): 1035-43.
- McCluskey, Stephen C., "Historical Archaeoastronomy: The Hopi Example," from *Archaeoastronomy in the New World*, A.F. Aveni (ed.) (Cambridge: Cambridge University Press, 1982).
- Kidwell, Clara Sue, "Ethnoastronomy as the Key to Human Intellectual Development and Social Organization," in *Native Voices: American Indian Identity and Resistance*, Richard A. Grounds, George E. Tinker, and David E. Wilkins (eds.) (Lawrence, Kansas: University Press of Kansas, 2003), pp. 5-19.

Extended Reading:

- Aveni, Anthony, *Skywatchers of Ancient Mexico* (Austin: University of Texas Press, 1980).
- Chamberlain, Von Del, *When the Stars Came Down to Earth: Cosmology of the Skidi Pawnee Indians of North America* (Los Altos, California: Ballena Press, 1982).
- Edmonson, Munro S., *The Book of the Year: Middle American Calendrical Systems* (Salt Lake City: University of Utah Press, 1988).
- Reyman, Jonathan E., "Astronomy, Architecture and Adaptation at Pueblo Bonito," *Science*, *193* (4257) (September 10, 1976): 957-62.
- Sofaer, A., Zinser, V., and Sinclair, R., "An Anasazi Solar Marker?" *Science*, *209* (4459) (August, 1980): 858-60.

Film:

"The Sun Dagger," available through the Extension Media Services, University of California, Berkeley. It shows the passage of a streak of light through a spiral carved into a rock face at Fajada Butte, New Mexico, which has been interpreted as an ancient Pueblo solstice marker.

The primary journal for the study of archaeoastronomy is *Archaeoastronomy*, published by the Center for Archaeoastronomy at the University of Maryland, directed by John Carlson.

Day 2
Mathematics

Mathematics is an essential tool of science in that it allows manipulation of information about relationships among objects. Mathematical systems in the Americas range from the highly developed base 20 system of the Mayan cultures to very simple counting systems noted on one's fingers. The Mayan system was used for calendrical notations rather than operations such as multiplication or division. It was important for keeping linear count of the days in the Long Count and for keeping track of the correlation between the 260-day ritual calendar and the 360-day Vague Year.

Other systems of recording and manipulating numerical information include the quipu of the Inka, a series of knotted cords tied to a main cord. The patterns of knots are thought to be a kind of numerical system to keep track of quantities of goods for trading purposes or held as tribute by the Inka (emperor). Unlike the Mayan system, where scholars have made significant progress in recent years in deciphering hieroglyphic writing, the code of the quipu has not been broken. Contemporary Andean people still use quipus but their use does not obviously correspond to the use at the time of European contact when they were first observed. It is possible that part of their purpose was to record celestial cycles.

The system of directional shrines that encompasses the city of Cuzco in Peru today has been likened to a quipu laid over the city, dividing it into ceremonial zones controlled by different groups of people during different parts of the year. The shrines may mark the passage of the sun and moon and divide the Inka universe not only into discrete units of time but also into political or religious units.

Without readily translatable explanatory texts, contemporary scholars must work backward from the visible results of the intellectual activities of the precontact cultures of the Americas to try to reconstruct the origins of those activities. This is particularly true in the case of mathematical systems.

Student Reading

- R. T. Zuidema, "The Inca Calendar," in *Native American Astronomy*, Anthony F. Aveni (ed.) (Austin: University of Texas Press, 1977), p. 231.
- Mayan Math, available from the web site of the Exploratorium, San Francisco, California. On-line address: http://www.exploratorium.edu/ancientobs/chichen/HTML/TG-math.html

Extended Reading

- Ascher, Marcia and Ascher, Robert, *Code of the Quipu: A Study in Media, Mathematics and Culture (*Ann Arbor: University of Michigan Press, 1980).
- Aveni, Anthony, Gibbs, Sharon L., and Hartung, Horse, "The Caracol Tower at Chichen Itza: An Ancient Astronomical Observatory?" *Science*, *188* (June 6, 1975): 977-85.
- Closs, Michael P. (ed.), *Native American Mathematics (*Austin: University of Texas Press, 1986).
- Lounsbury, Floyd G. "Maya Numeration, Computation and Calendrical Astronomy," *Dictionary of Scientific Biography*, *15*, Supplement (New York: Scribners, 1978), pp. 759-818.

Day 3
Environmental Management

Human beings act upon and are acted upon by their environments. This mutual interaction is a process that shapes both environment and culture. Native people took an active role in shaping their environments through the use of fire, irrigation systems, and domestication of plants. Indians in North and South America adapted to an incredibly wide range of environments and spoke an incredible variety of languages, and this diversity must be acknowledged.

Indian people managed their environments by fire, water, and deliberate cultivation of stands of wild plants. Burning in grasslands controlled the extent of forest areas. In wooded areas it provided new browse for animals. It cleared fields for agriculture and created nutrients for the soil. Fire had significant ceremonial association for many tribes because it was associated with the Sun. The Lakota saw the Sun as one of their primary dieties, and they set fire to prairie grasses occasionally to drive buffalo to areas where they would be killed for food.

Hohokam farmers in the Arizona desert built extensive irrigation systems to develop their agricultural system. In Chaco Canyon, New Mexico, Puebloan peoples constructed the single largest dwelling in North America prior to the early twentieth century—Pueblo Bonito, a five-story tall ediface that had approximately 800 rooms. An elaborate water control system channeled water down the walls of the steep canyon. The system allowed for agriculture that provided subsistence for the approximately 25,000 people who lived along the Chaco River flowing through the canyon. The system could not, however, overcome the effects of a period of severe drought from 1130 to 1190 C.E. The Chaco Culture dissipated, and the population dispersed.

Current debates over global warming indicate the limitations of current scientific theories to account with absolute precision for natural phenomena. Students should be able to think about how environmental management affects their own lives, how people's pragmatic use of the environment affects their survival, how attempts to control the environment have effects on all things—plants, animals, and humans—in the environment, and how scientists are limited in their ability to control the environment.

Student Reading

- Day, Gordon, "The Indian as an Ecological Factor in the Northeastern Forest," *Ecology*, *34* (2) (April, 1953): 329-46.

Extended Reading

- Haury, Emil W. *The Hohokam: Desert farmers and Craftsmen* (Tuscon: University of Arizona Press, 1976).
- Lewis, Henry T., *Patterns of Indian Burning in California: Ecology and Ethnohistory*, Ballena Press Anthropological Papers, No. 1 (Socorro, New Mexico: Ballena Press, 1973).
- Vivian, R. Gwinn "Conservation and Diversion: Water-Control Systems in the Anasazi Southwest," in *Irrigation's Impact on Society*, Theodore E. Downing and McGuire Gibson (eds.), Anthropological Papers of the University of Arizona, Number 25 (Tucson: The University of Arizona Press, 1974).

Day 4
Agriculture

Domestication of plants marks a signal human achievement in the advance of culture. It is based on systematic observation and human selection of desirable qualities in plants. It also entails establishing a symbiotic relationship between humans and plants—plants feed humans. Domestication of plants occurred when Native people (most likely women, since they were the primary gatherers) selected the seed heads that held the seeds most tightly, thereby providing the gatherer the greatest return for her effort. This selection on a regular basis favored plants which could not broadcast their own seeds and which became dependent on humans to detach seeds from stems and plant them.

Although corn is generally considered the epitome of Indian agriculture, other plants were domesticated and played important roles in subsistence patterns through the eastern woodlands. Indians in meso and south America are credited with the domestication of corn and potatoes, but recent scholarship reveals that Indians in the eastern woodlands of North America domesticated sun flowers, chenopodium, sumpweed, marsh elder, may grass, and possibly squash. Although these plants declined in importance as food sources when corn, a more nutritious and stable crop, was introduced into the eastern woodlands from mesoamerica, native people made the woodlands an independent agricultural hearth relatively recently recognized.

The triad of corn, beans and squash became the staple agricultural complex for agriculturalists throughout North America by the end of the first millenium C.E. Although Native people did not conceptualize the modern relationships of beans as nitrogen fixers and corn as a nitrogen processor, they generally recognized a mutual dependency among the three crops. Beans could use corn stalks to climb, and squash leaves provided a ground cover that kept soil cool and uniformly moist.

Student Reading

- Cowan, C. Wesley, "Understanding the Evolution of Plant Husbandry in Eastern North America: Lessons from Botany, Ethnography and Archaeology," in *Prehistoric Food Production in North America*, Richard I. Ford

(ed.), Anthropological Papers, Museum of Anthropology, University of Michigan, No. 75 (Ann Arbor: University of Michigan, 1985), pp. 207-217.

Extended Reading

- Hurt, R. Douglas, *Indian Agriculture in America: Prehistory to the Present* (Lawrence, Kansas: University Press of Kansas, 1987).
- Scarry, C. Margaret (ed.), *Foraging and Farming in the Eastern Woodlands* (Gainesville: University Press of Florida, 1993).
- Smith, Bruce D., *Rivers of Change: Essays on Early Agriculture in Eastern North America* (Washington and London: Smithsonian Institution Press, 1992).
- The *Seedhead News*—issued by Native Seeds/SEARCH, 2509 North Campbell Avenue #325, Tucson, Arizona 85719—contains information about growing indigenous crops.

Film:

"Hopi: Songs of the Fourth World" is available from New Day Films, 22D Hollywood Avenue, Ho-Ho-Kus, New Jersey 07423. It shows the importance of corn in the culture of the Hopi Indians.

Day 5
Medical Practices

The uses of medicinal herbs and plants by Native Americans represent a particular world view concerning power in the environment. In contemporary society, Native uses of plants have received attention as a source of commercially valuable pharmaceuticals. Many people are aware that aspirin is a synthetic form of natural components found in willow bark, which was widely used by Indians in teas brewed to treat fever and pain. Scholars have recorded extensive evidence of pragmatic uses of plants by native people, and some have attempted to correlate the expected outcome indicated by those uses with chemical components of plants that can produce specific physical effects.

The modern scientific explanation of native curing practices involves chemical components of plants that cause changes in the human body. Native people attributed the changes to the sentient spirits of the plants who responded to human appeals for assistance. Knowledge of medicinal herbs was generally esoteric in that certain practitioners had particular things that they used. In some cases, such as the Midewiwin or Grand Medicine Society of the Chippewa in the Great Lakes region, knowledge of herbs was passed on as part of initiation into the Society.

Medical practices among non-Indian colonists and Native people in nineteenth-century America were very similar. White settlers brought the tradition of medicinal "simples" from Europe, and they readily adopted herbal remedies that they learned from Indians or that resembled European "simples." Indian practices of bleeding or cupping represented the same kind of mechanical manipulation that European physicians used. Pragmatic treatment of dislocated joints involved tying a rope around the affected limb, throwing it over a tree branch, and pulling the joint back into place. On the Great Plains, fractures were

splinted with rawhide, which dried and tightened around the broken limb. A small window was cut in the hide to allow access to wounds caused by compound fractures.

A typical treatment regimen for generalized aches and fevers was that prescribed by Iroquois curers in upstate New York. The patient was put through a sweat lodge for purification, given large quantities of willow bark tea to drink (willow bark contains salicen, the natural source of acetyl salacylic acid—aspirin), and then wrapped in buffalo robes and put in the corner of the longhouse to rest for several days. The cure was usually effective. Medicine is more of an art than a science, but its practice depends upon careful observation of cause and effect relationships and systematic application of knowledge. In this regard, Amerian Indian medicine was as efficacious as the European medical practices that were imported into the Americas, and the two systems were based on many of the same principles.

Student Reading

- Virgil Vogel, *American Indian Medicine* (Norman: University of Oklahoma Press, 1970), Chapters I, II, V, VI, VII.

Extended Reading

- Moerman, Daniel, *American Medical Ethnobotany: A Reference Dictionary* (New York: Garland Publishing Company, 1977).
- Frances Densmore, "Uses of Plants by the Chippewa Indians," in *Forty-fourth Annual Report of the Bureau of American Ethnology to the Secretary of the Smithsonian Institution, 1926-27* (Washington: United States Government Printing Office, 1928).
- Ortiz de Montellano, Bernard, "Empirical Aztec Medicine," *Science*, *188* (April 18, 1975): 215-20.

Day 6
The Concept of Ethnoscience

The act of categorizing natural phenomena is an important aspect of science. The Linnean system is still the basis of modern botany. Native people developed their systems of categorization based on their observations of the world. These were specific to groups rather than applied universally, but in each case they represented a way of organizing knowledge, and in some cases they had predictive power.

The Navajo in the American Southwest, for instance, classify plants (as well as rain) as male and female. Woody plants are male, while pliable plants are female, and this categorization is based on physical characteristics associated with behavioral characteristics. Birds and storms were identified with each other among the Saulteaux, an Ojibwa band around the Berens River in Ontario, because birds followed the same paths as storms in their yearly migrations. A very rational inference based on systematic observation is that birds cause the storms. The Saulteaux associated storms with birds in the Thunderbird, a great, powerful, and very real being.

Another example of classification based on association can be found among the Thompson Indians of British Columbia. The woodbetony (*Pedicularis bracteosa*), which they used in basketmaking, was with species of willow weed (*Epilobium*), and its name was *skikens a. sha'ket*, meaning "companion of willow weed." Association could be based on behavior. The Navajo put bats in the same category as insects because of an origin tradition in which insects and bats lived together in a previous world. The badger was classified with the wolf, mountain lion, bobcat and lynx (which were grouped as predatory animals) because he was their friend.

Classification systems were important to native people, and they reveal the results of careful observation and thinking about the nature of the world. The categories in those systems are more likely to be based on their usefulness to humans or associations with other beings in the physical world than to simple physical form. Contemporary science judges the validity of native classification systems by how well native names distinguish among animals and plants of different genera and species, i.e., how closely native people recognize the same features that scientists do. But the Tzetzal in Chiapas, Mexico, distinguish relatively few of the modern botanical categories of plants in their environment. They do, however, distinguish a number of different kinds of beans within a single modern species. And they lump numbers of species together in single names. In other words, they find many differences in plants that are important to them, and very few in those that are not.

The commonplace knowledge that "Eskimos have fifty names for snow" should be interpreted as acknowledging the ability of Native people in arctic regions to make fine discriminations among kinds of snow—a skill often necessary to their survival and often predictive of changing environmental conditions. The ability both to categorize and to recognize subcategories is based on the power of sustained and consistent observation of the environment.

Student Reading

- Hallowell, A. Irving, "Some Empirical Aspects of Northern Saulteaux Religion," *American Anthropologist*, n.s., *36* (1934): 389-404.
- Elsie Viault Steedman, (ed.), "Ethnobotany of the Thompson Indians of British Columbia, based on Field Notes by James A. Teit," in *Forty-Fifth Annual Report of the Bureau of American Ethnology 1927-28* (Washington, D.C.: Smithsonian Institution, 1930), pp. 450-51, 468, 500.
- Reichard, Gladys A. "Navajo Classification of Natural Objects," *Plateau*, *21* (1) (July 1948): 7-8.
- Berlin, Brent, Dennis E. Breedlove, and Peter H. Raven, "Folk Taxonomies and Biological Classification," *Science*, *154* (October 14, 1966): 61-65.

Possible Topics for Student Research

1. How does a particular tribe use plants, and in what ways do those uses represent scientific activity?
2. Students may practice their own naked-eye observations of celestial events over a certain period and study native accounts of the stars that they see. They can then assess how tribal explanations differ from modern astronomical ones for what they have viewed.
3. How can agricultural practices in a particular tribe conform to principles of contemporary ecology?
4. How do traditional agricultural practices promote genetic diversity or uniformity in plants? Why is genetic diversity important?

LATIN AMERICA

Marcos Cueto
and
Jorge Cañizares Esguerra

INTRODUCTION

As the first colonial outpost of the early-modern European world, Latin America has long witnessed complex processes of cultural cross-pollination, suppression, and adaptation. Beginning in the fifteenth century, millenarian Amerindian civilizations, heirs to rich local "scientific" traditions, seemingly gave way to European institutions of learning and to new dominant forms of representing the natural world. What happened to the earlier modes of learning? How do subordinate cultures resist and adapt to new forms of knowledge? Latin America has long been a laboratory where the "West" has sought to domesticate and civilize "non-Western" forms of Amerindian and African knowledge.

Given Latin America's rich history of cultural adaptations, suppressions, and hybridizations, it cannot be labeled non-Western without serious qualifications. From the fifteenth century, Western modes and styles of apprehending the natural world have influenced all learned elite institutions in the region. Latin America has witnessed different periods of Western scientific dominance; Iberian, French, British, German and USA scientific traditions and institutions have left indelible marks.

Many scholars have attempted to account for the diffusion of Western scientific knowledge in Latin America and the Third World. Negative interpretations have overemphasized Latin America's passivity and patterns of cultural and economic dependency to explain the region's stunted scientific development. They have also used the history of science in Latin America as a foil for the technological and scientific successes of the West--identifying conditions that have purportedly made scientific and technological successes possible in other parts of the world (e.g., the Reformation and vigorous industrial development).

But a more positive point of view can yield strikingly different historical narratives. Latin Americans have been able to create rich and complex national scientific traditions in conditions of adversity that include shortages of funds for salaries and equipment, small libraries, inadequate supplies, and political instability disrupting the continuity of scientific work. Overcoming these difficulties, Latin Americans have contributed significantly to the world's store of knowledge. Tropical medicine and physiology at the turn of the twentieth century illustrate this: Carlos Chagas, a microbiologist in Rio de Janeiro, discovered the parasite trypanosome responsible for a disease affecting Brazilian peasants that now bears his name. The Cuban Carlos Finlay identified the vector of yellow fever. The Peruvian Carlos Monge studied the effects of high-altitude in human beings and animals. The Argentine physiologist Bernardo Houssay

related hypophysis with diabetes mellitus and received a Nobel Prize in 1947. Though "pure" science has not attracted large numbers of devotees and patrons in the region, rich traditions have emerged in "applied" fields of natural history and medicine (including public health and technology).

This chapter's positive approach to the history of science in Latin America examines the institutional and social contexts in which scientific ideas and practices have evolved. Given the rich colonial and post-colonial history of the area, this chapter also explores the history of transference, adaptation, and hybridization of knowledge. It delves into a multiplicity of topics, including the scientific and technical legacies of Amerindian civilizations; the dynamic and traumatic cultural encounter of conflicting representations of nature; and the arrival and creative assimilation of Western knowledge and institutions in colonial (1492-1820s) and post-colonial (1820s-1990s) societies.

A survey of the history of science and technology in Latin America should first come to grips with the remarkable contributions to arithmetic, botany, astronomy, and metallurgy of the ancient Mesoamerican and Andean civilizations. Unfortunately, the scientific and technical accomplishments of these civilizations, as well as their continuity, adaptation, and mutation in the wake of European colonization, are incompletely understood and require further investigation.

The history of science in colonial Latin America also deserves greater study. A secular-liberal reading of the colonial past widely accepted during the early nineteenth-century still influences many scholars. According to this view, even though Spain instituted vigorous colonial cultural policies that included the early creation of universities (which opened some one hundred years earlier than North America's Harvard), Spain's commitment to religious intolerance (Inquisition) and to an old-fashioned scholastic mentality stifled scientific institutions and methods. But it is becoming increasingly clear that Western scientific ideas, institutions, and activities significantly affected the Iberian colonies. Initially they legitimized European colonialist practices. Later they became central to imperial policies of economic renewal. By the end of the colonial period, they would play a major role in creating discourses of national identity among the local elites.

After independence, scientific institutions and practices declined in the wake of destruction brought about by the wars. Nevertheless, medical doctors, naturalists, military engineers, and savants assumed important sociopolitical roles. They became leading figures in the state bureaucracy, identified raw materials of possible commercial value for the non-industrialized export economies, used scientific rhetoric to settle political debates (by the second half of the nineteenth century, Positivism had become the leading elite ideology), and deployed scientific knowledge and imagery to consolidate national ideologies.

As the new nation-states began slowly to consolidate, scientific institutions and practices recovered their prominence. Many European scientists (particularly naturalists) arrived in Latin America in the second half of the nineteenth century, and along with local scientific communities, helped to map and catalog national resources. They also created the technical and financial conditions for extending the reach of the state through developments of railroads, telegraphs, mining, export agriculture, and public health. In the

twentieth century, scientific discourses and their accompanying ideological and socio-economic practices have continued to evolve through periods of profound social, political, and economic change.

Students need to be aware that this introduction to the region's rich history of science is considerably limited by the available resources in English secondary literature we review. A large corpus of knowledge in Spanish, Portuguese, and French beckons those with the linguistic skills to exploit them.

Important themes highlighted in the following are:

- Scholarship on the history of science and medicine of an important region of the "Third World"
- Contemporary debates on the implications of scientific and technical change from the perspective of the so-called periphery
- The complex and often conflicting relationship between the scientific and professional elites of "underdeveloped" countries and those of North America and Europe
- The independent and interacting influence of national and international factors on the development of science in Latin America
- Indigenous reactions to scientific programs and ideas of progress

For a one-volume history of Latin America, see:

Benjamin Keen, *A History of Latin America*, 5th ed. (Boston: Houghton Mifflin, 1996).

No single volume covers the entire history of science in Latin America. However, the following items provide coverage of specific historical periods:

- Thomas P. Glick, "History of Science in Latin America," *The Cambridge Encyclopedia of Latin America and the Caribbean*, 2nd ed. (Cambridge: Cambridge University Press, 1992), pp. 451-457.
- Jorge Cañizares-Esguerra, *Nature, Empire, and Nation: Explorations of the History of Science in the Iberian World (*Stanford: Stanford University Press, 2006).
- Marcos Cueto, (ed.), *Missionaries of Science: The Rockefeller Foundation and Latin America (*Bloomington: Indiana University Press, 1994).

The two most significant journals published in Latin America are:

- *Historia, Ciencias, Saúde-Manguinhos*
  Address: Casa Oswaldo Cruz, Prédio do Relógio, Av. Brasil, 4365, Rio de Janeiro, RJ Brasil 21040-360. Telf. (021) 280-9241, Fax (021) 598-4437.
- *Quipu, Revista Latinoamericana de Historia de las Ciencias y la Tecnología*
  Address: Apartado postal 21-873, 04000 Mexico D.F., Mexico.

DAY 1
Non-Western Sciences

The literature on the history of science of native-American societies is scarce, in contrast with the rich scholarship available on non-Western scientific traditions in China, India, and the Middle East. A research program on Mesoamerican and Andean science comparable to that developed by Joseph Needham on China has yet to appear. For too many scholars, Amerindian representations of nature and forms of knowledge become valuable only when they parallel Western learned disciplines. For example, we know more about Mesoamerican calendrical systems than other scientific areas, because arguments about whether native Americans were "civilized" were believed to hinge upon the inferiority, equality, or superiority of their astronomical assumptions to those of the West.

Ethnohistorians and archeologists have managed to increase our understanding of ancient Amerindian systems of knowledge without prying them out of their cultural matrices. Anthropologists, for example, have successfully and methodically reconstructed ancient Amerindian views of nature and the body.

We have much to learn about the impact of the European conquest and colonization on Amerindian systems of knowledge. During the colonial and post-colonial periods, the literate Amerindian elites—keepers of learned traditions—either disappeared or were acculturated. Amerindian systems of knowledge moved thus to the margins of Latin American societies where they changed, adapted to, and merged with forms of folk Catholicism. Most of today's suggested readings explore the subject of indigenous representations of the body and interaction of these with Western views.

Student Reading

- Joseph W. Bastien, "Qollahuaya-Andean Body Concepts: A Topographical-Hydraulic Model of Physiology," *American Anthropologist, 87* (1985): 595-611.
- George M. Foster, "On the Origin of Humoral Medicine in Latin America," *Medical Anthropology Quarterly, 1* (1987): 355-393.
- Joseph W. Bastien, "Differences between Kallawaa-Andean and Greek-European Humoral Theory," *Social Science and Medicine, 28* (1989): 45-51.

Extended Reading

- David Hess, *Spirits and Scientists: Ideology, Spiritism, and Brazilian Culture* (Pennsylvania State University Press, 1991).

- Constance Classen, *Inca Cosmology and the Human Body (*Salt Lake City: University of Utah Press, 1993).
- Alfredo Lopez-Austin, *The Human Body and Ideology: Concepts of the Ancient Nahuas*, 2 vols. (Salt Lake City: University of Utah Press, 1988).
- Michael Taussig, *Shamanism, Colonialism, and the Wild Man: A Study in Terror and Healing (*University of Chicago Press, 1987).

Videos

- *Birth and Belief in the Andes of Ecuador* (1995), 28 min. Available through University of California Extension, Center for Media and Independent Learning (phone 510-642-0460). It explores contemporary beliefs and practices surrounding childbirth and infant care in the northern Andes.
- *The Chinampas* (1990), 31 min. Also available through University of California Extension. The video "examines an ecologically sustainable system of agriculture that has flourished in Mexico for some 2,000 years."
- *The Maya Pompeii* (1996), 47 min. Also available through University of California Extension. This documentary is a good introduction to Maya achievements in agriculture, architecture, astronomy, and art.

Possible Topics for Student Research

1. Taking your cues from Bejamin Keen's *The Aztec Image in Western Thought*, trace how western scholars (including Mexicans) have understood and studied Mesoamerican calendars and astronomy over the centuries. Have the religious and political agendas of these scholars contributed to shape their understanding of indigenous astronomy? If so, how?
2. Using Marcia and Robert Ascher's *Code of the Quipu* as your springboard for further research, trace the basic outlines of Inca arithmetic and mathematics and the cultural matrix in which they emerged.
3. "Landscapes and economic and political systems seem to have shaped the ways most cultures have understood the workings of the body." To determine whether this statement is true, compare Andean representations of the body with readings on Chinese-Confucian, Hindu-Ayurvedic, and Greek-Humoral views in *Knowledge and the Scholarly Medical Traditions,* edited by Don Bates.

DAY 2
COLONIAL TRADITIONS: BAROQUE SCIENCE (1500-1750)

Spaniards and Portuguese brought to the New World their own forms of Western science and did not attempt to assimilate local learned traditions. Europeans incorporated the New World's plants into their therapeutic arsenal mainly because they thought that nature had been wondrously designed by a God who had distributed the plants of the world to match and cure each region's endemic diseases. In the sixteenth century, the Spanish Crown sought to map the New World and its rich botanical resources. For example, the Crown distributed questionnaires to local authorities who collected valuable information on plants

and geography known as the *Relaciones Geográficas*. The expedition of Francisco Hernández to Mexico in the 1570s was supported by royal patronage.

As universities and courts mushroomed in the colonies, European scientific traditions thrived: Medieval, Renaissance, and Baroque discourses and practices often overlapped and coexisted. Colonial universities trained theologians, lawyers, and a few physicians in neo-scholastic paradigms that helped sustain a society organized on corporatist principles and hierarchical social and racial estates.

Colonial courts, private libraries, pharmacies, and cloisters often became alternative institutional channels to the universities and helped spawn more 'modern' scientific practices. Baroque polymaths such as Diego Rodríguez, Carlos Siguenza, and Sor Juna Inés de la Cruz kept cabinets of curiosities, maintained alchemical laboratories, and worked with microscopes, telescopes, and astrolabes. They were summoned by the state to cast horoscopes and produce maps, machines, and courtly mechanical toys. Baroque science was closely linked to symbolic rituals that affirmed church and dynastic powers in religious and civic public ceremonies. Artists and scientists collaborated to uncover the underlying hidden signatures of nature in order to manipulate its forces.

Student Reading

- Guenther B. Risse. "Medicine in New Spain," *Medicine in the New World, New Spain, New France and New England*, Ronald Numbers, (ed.) (Knoxville: The University of Tennessee Press, 1987), pp. 12-63.
- Jorge Cañizares-Esguerra, "Spanish America: From Baroque to Modern Colonial Science," in *The Eighteenth-Century*, Roy Porter, (volume ed.), pp.718-738.
- David Lindberg and Ronald Numbers, (general eds.), *The Cambridge History of Science,* Vol 4 (Cambridge University Press, 2003).

Extended Reading

- Anthony Pagden, *The Fall of Natural Man: The American Indian and the Origins of Comparative Ethnology (*Cambridge: Cambridge University Press, 1986).
- John Tate Lanning, *The Royal Protomedicato: The Regulation of the Medical Profession in the Spanish Empire*, John Jay (ed.) (Tepaske, Durham: Duke University Press, 1985).
- Luis Martin, *The Intellectual Conquest of Peru: The Jesuit College of San Pablo 1568-1767* (New York: Fordham University Press, 1968).
- Octavio Paz, *Sor Juana: Or, The Traps of Faith*, Margaret Sayers Peden, (trans.) (Cambridge: Harvard University Press, 1989), pp. 155-168, 174-179, 238-260, 357-386.

Possible Topics for Student Research

1. Building upon Pagdenís, *The Fall of Natural Man*, explore the connections between the social sciences and colonialism in Spanish America.
2. Using Paz's *Sor Juana* and Cañizares-Esguerra's "Spanish America," explore how the sciences of optics, music, astrology, alchemy, and mechanics helped bolster and legitimize colonial authorities.

DAY 3
COLONIAL TRADITIONS: BOURBON SCIENCE (1750-1820)

Some new currents of the Scientific Revolution arrived in the colonies in the period 1750-1820. They were accompanied by a program of economic and cultural renewal launched by Charles III in Spain and the Marquis of Pombal in Portugal that dramatically changed Iberia and its colonies in the second half of the eighteenth century. The mechanical philosophy of Descartes and Newton was made widely available by colonial physicians who embraced the iatromechanical views of Boerhaave. On the other hand, the heliocentric models of Galileo and Newton were not introduced in most of the newly reformed colonial universities (the Jesuits were expelled from Portuguese and Spanish territories, and the schools and universities they controlled were reorganized by a Jansenist and royalist secular church from the 1770s on).

Spain and France sponsored numerous scientific expeditions to their colonial outposts. As Spain launched economic reforms to turn its colonies into dependent, specialized mining and agro-export producers, the state supported many expeditions to chart, catalog, and map the hitherto untapped botanical resources of the New World (woods for shipbuilding, plant drugs, minerals, organic dyes, and agricultural produce). Authorities also generously patronized naturalists as part of the Spanish crown's patriotic campaign to disabuse Europe of the view of Spain as an ignorant country whose glories lay in the past.

Interestingly, the local colonial elites (Creoles) also embraced the new science in efforts to create alternative proto-national discourses. As Creoles faced discrimination from the new Bourbon regime, they sought to separate their identities from Spain. This coincided with the spread in Europe of (French naturalist) Buffon's claim that the American continent was a humid and degenerating land. Creole scientists—including Hipolito Unanue from Peru and Antonio de Alzate from Mexico, among many others—opposed Buffon's views by exalting the natural wonders of the colonies. They attempted to build a patriotic science on the premise that America did not abide by "natural laws" expounded by Europeans.

Student Reading

- Thomas Glick, "Science and Independence in Latin America," *Hispanic American Historical Review, 71* (1991): 307-334.
- Jorge Cañizares-Esguerra, “How Derivative Was Humboldt? Microcosmic Nature Narratives in Early Modern Spanish America and the (Other) Origins of Humboldt’s Ecological Ideas,” in Londa Schiebinger and Claudia Swan, (eds.), *Colonial Botany: Science, Commerce, and Politics in the Early Modern World (*Philadelphia: University of Pennsylvania Press, 2004), pp. 148-65.

Extended Reading

- Robert R. Steele, *Flowers for the King: The Expedition of Ruiz and Pavon and the Flora of Peru (*Durham: Duke University Press, 1982).

- John Tate Lanning, *The Eighteenth-Century Enlightenment in the University of San Carlos Guatemala* (Cornell University Press, 1956).
- Donald B. Cooper, *Epidemic Disease in Mexico City, 1817-1813: An Administrative, Social and Medical Study (*Austin: University of Texas Press, 1965).
- James E. McClellan III, *Colonialism and Science: Saint Domingue in the Old Regime (*Baltimore: The John Hopkins University Press, 1992).
- H. W. Engstrand, *Spanish Scientists in the New World: The Eighteenth Century Expeditions (*Seattle: University of Washington Press, 1981).

Possible Topics for Student Research

1. Taking your leads from the article by Glick, study the ways in which Spanish American Creoles sought to create distinct local sciences and how these attempts helped foster nationalist and secessionist forces in the colonies.
2. Using Steele's and Cañizares-Esguerra's texts as springboards for further research, reconstruct the ties between the Bourbon colonial reforms and the avalanche of scientific expeditions that followed in the wake of the reforms. Compare the results of your investigation with the conclusions reached by McClellan on French scientific activities in Haiti.
3. Taking your cues from Lanning's and Cooper's books, build an argument to challenge those who have sustained that colonial Spanish America was scientifically and intellectually backward.

DAY 4
SCIENCE AND THE STATE DURING THE 19TH CENTURY (1820-1880)

During the 19th century, science did not develop in an autonomous public sphere but under the shadow of the emergent republics of Latin America. This occurred because local scientific communities were fragile, the colonial legacy persisted, and the governments monopolized resources. In addition, the states encouraged a view that science was a source of modern professional education, economic benefits, and public entertainment.

As European scientists advanced ever more comprehensive scientific theories, new levels of international scientific cooperation developed. The number, diversity and scope of international scientific expeditions to Latin America increased. These new international scientific networks lent their support to local political leaders and savants who were implanting scientific and technical education in their countries. The formation or reorganization of professional universities followed the French model of higher education, which had little regard for the experimental dimension of science. Local scientific traditions emerged in different cities, and a number of scientific institutions began to appear such as botanical gardens, specialized libraries, museums of natural history, physiology laboratories, and scientific chairs in medical schools.

Darwinism had some influence in Latin America. With few exceptions, Darwinian theory was brought to Latin America by physicians, politicians, and

social scientists as a new ideological resource to settle debates over social order and material progress.

Student Reading

- Lewis Pyenson, "Functionaries and Seekers in Latin America: Missionary Diffusion of the Exact Sciences, 1850-1930," *Quipu, 2* (1985): 387-420.
- Julyan Peard, *Race, Place, and Medicine: The Idea of the Tropics in Nineteenth Century Brazilian Medicine* (Durham, North Carolina: Duke University Press, 1999).

Extended Reading

- Frank Safford, *The Ideal of the Practical: Colombia's Struggle to Form a Technical Elite (*Austin and London: University of Texas Press, 1976).
- Roberto Moreno, "Mexico," in *The Comparative Reception of Darwinism*, Thomas Glick, (ed.) (Chicago: The University Of Chicago Press, 1988).
- R. R. Miller, *For Science and National Glory: The Spanish Scientific Expedition to America, 1862-1866* (Norman, Oklahoma: University of Oklahoma Press, 1968).
- Sidney Chalhoub, "The Politics of Disease Control: Yellow Fever and Race in 19th Century Brazil," *The Journal of Latin American Studies, 25* (1993): 441-464.
- Daniel R. Headrick, *The Tentacles of Progress: Technology Transfer in the Age of Imperialism, 1850-1940 (*New York: Oxford University Press, 1988).
- Lucille Brockway, *Science and Colonial Expansion: The Role of the British Royal Botanic Gardens (*New York: Academic Press, 1979).

Possible Topics for Student Research

1. Compare the reception of Darwinism in Argentina, Brazil, and Mexico. Determine they way in which debates over the racial composition of each of these countries affected the reception of Darwinism.
2. Analyze the ways in which state building fostered and/or hampered scientific development.
3. Consider nineteenth-century international scientific networks as engines and/or obstacles for scientific growth in Latin America.
4. Examine the reception of tropical medicine in Bahia, Brazil, and the re-creation of an European tradition

DAY 5
THE EMERGENCE OF NATIONAL TRADITIONS (1880-1950)

At the turn of the twentieth century, some Latin American countries created laboratories with national visibility and impact. There, cadres of local scientists began to do experimental work that would gain them international notoriety. Among those who won the recognition of their peers abroad were researchers at bacteriological and physiological institutes in Cuba (Carlos Finlay), Brazil (Carlos Chagas), Argentina (Bernardo Houssay), and Peru (Carlos Monge). These institutes emerged in a period marked by nationalism, economic growth, and governmental support for the promotion and reorganization of cultural activities. Moreover, in the wake of the Spanish Civil War (1936-1939), a number of exiled Republican Spanish scientists arrived in various Latin American countries and invigorated experimental science. The new experimental institutes imaginatively adapted to adverse conditions, scarce resources, and low public esteem.

From the 1920s, the Rockefeller Foundation and other private and public agencies from the US and Europe played major roles in the organization of scientific and technical knowledge in Latin America. As Latin America became fully integrated into the global capitalist economy, the U.S. and Europe made it a matter of policy to influence the cultural values of the local elites. Over the course of this century, the U.S. influenced Latin American learned communities through the medical and scientific practices that accompanied the invasions, occupations, and work performed by its armed forces and private companies in the region. More lasting and subtle was the work of North American foundations (such as the Rockefeller and Kellogg Foundations) in the rise of national scientific organizations and nationwide health services. The relationship between American philanthropy and Latin American science was not a case of unilateral diffusion. Latin Americans reacted and adapted to the models of organization of science and higher education exported from the U.S. But Latin American scientists did not alone accommodate the new models to local circumstances. U.S. scientists and even field officers of the Rockefeller proved in some cases more flexible than the Latin Americans themselves. Locals and foreigners engaged in negotiations about how best to replicate institutions across space and culture, and whether changes had come primarily from domestic influences or from external stimuli.

Student Reading

- Marcos Cueto, "Laboratory Styles and Argentine Physiology," *Isis*, *85* (1994): 228-246.
- Julia Rodri□guez, *Civilizing Argentina: Science, Medicine, and the Modern State* (Chapel Hill: University of North Carolina Press, 2006).

Extended Reading

- Nancy Leys Stepan, "*The Hour of Eugenics": Race, Gender and Nation in Latin America (*New York: Science History Publications, 1996).

- Nancy Leys Stepan, *The Beginnings of Brazilian Science: Oswaldo Cruz, Medical Research and Policy, 1890-1920 (*New York: Science History Publications, 1976).
- Teresa Mead, "Cultural Imperialism in Old Republic Rio de Janeiro: The Urban Renewal and Public Health Project," in Teresa Meade and Mark Walker, (eds.), *Science, Medicine and Cultural Imperialism (*New York: St. Martin's Press, 1991), pp. 95-119.
- Marcos Cueto, "Indigenismo and Rural Medicine in Peru: The Indian Sanitary Brigade and Manuel Nunez Buitron," *Bulletin of the History of Medicine, 65* (1991): 22-41.
- Lewis Pyenson, "The Incomplete Transmission of European Image: Physics at Greater Buenos Aires and Montreal, 1890-1920," *Proceeding of the American Philosophical Society, 122* (1978): 92-114.
- Francois Delaporte, *The History of Yellow Fever: An Essay on the Birth of Tropical Medicine (*Cambridge: The MIT Press, 1991).
- Simore P Kprof, Nara Azevedo, and Luiz O Ferreira, “Biomedical Research and Public Health in Brazil: The Case of Chagas Disease, (1909-1950),” *Social History of Medicine, 16* (2003): 111-130.

Possible Topics for Student Research

1. Were the institutionalization of experimental science and the coming of age of nationalism in the region in any way connected? Study the cases of Argentina, Peru, and Brazil.
2. Determine the ways in which the growth of institutes for experimental research (especially on tropical medicine) was related to the neocolonial economic prosperity enjoyed by Latin America countries from 1890 to 1930.
3. The Rockefeller Foundation’s impact in Latin America: A case of scientific neocolonial dependency or of local appropriation and adaptation of knowledge to adverse conditions?
4. Determine the kinds of scientific institutions and practices encouraged by the U.S. military presence in the region.
5. Identify cases of resistance to the hegemonic trend of Americanization of Latin American medical science

DAY 6
STRUGGLING TO SURVIVE (1950-1990)

Marginality, traditional values, scarce demand from local economic forces, and foreign dependence are considered factors that contribute to the meager societal support for or appreciation of scientists in contemporary Latin America. But during the past fifty years, a number of countries have demonstrated that science can evolve under adverse conditions. For example, during the 1950s, Argentina and Brazil created national councils of science and technology. In the following decade, Venezuela founded a major center for scientific research called the Instituto Venezolano de Investigaciones Científicas. Argentina has had a consistent nuclear policy since the 1950s and developed a nuclear power potential in the region.

Yet Latin America still must struggle to overcome isolation, lack of international visibility, and absence of a continuous scientific tradition. The public largely fails to appreciate that research is needed to achieve development. Administrative and political structures that encourage scientists to accomplish their work are undeveloped. Moreover, a significant proportion of scientists continue to depend on training abroad, which encourages a brain drain and disrupts the continuity of research. Another important theme addressed in this section will be the response of Latin American physicians and scientists to the challenges of pandemics of Cholera and AIDS.

Student Reading

- Simon Schwartzman, *A Space for Science: The Development of the Scientific Community in Brazil (*State College, PA: Pennsylvania State University Press, 1991).
- Steven P. Palmer, *From Popular Medicine to Medical Populism: Doctors, Healers, and Public Power in Costa Rica, 1800-1940 (*Durham: Duke University Press, 2003).

Extended Reading

- Hebe Vessuri, "The Universities, Scientific Research and the National Interest in Latin America," *Minerva, 24* (1986): 1-38.
- Jacqueline Fortes and Larissa Lomintz, *Becoming a Scientist in Mexico, the Challenge of Creating a Scientific Community in an Underdeveloped Country* (University Park, PA: Pennsylvania State University Press, 1994).
- Charles L Briggs and Clara Mantini Briggs, *Stories in the Time of Cholera: Racial Profiling During a Medical Nightmare* (Berkeley: University of California Press, 2003).
- Paul Farmer, *AIDS and Accusation: Haiti and the Geography of Blame* (Berkeley: University of California Press, 1993).
- Julie M. Feinsilver, *Healing the Masses: Cuban Health Policies at Home and Abroad* (Berkeley: University of California Press, 1993).
- R. Hilton, *The Scientific Institutions of Latin America* (Stanford: California Institute of International Studies, 1970).
- N. Patrick Peritore and Ana Karina Galve-Peritore, (eds.), *Biotechnology in Latin America: Politics, Impacts, and Risks* (Wilmington, Delaware: Scholarly Resources Books, 1995).

Videos

- *Jungle Pharmacy: Protecting the Global Environment* (1989). 53 min. Available through Cinema Guild (phone 212-246-5522). Explores connections between scientists, physicians and environmentalists from the "developed" world and "shamans" from the Amazon rain forest as they seek to turn the rain forest into a source of new drugs for the world.
- *Brazil: winning against AIDS* (2001). 27 min. Available through Bullfog Films (phone 610-779-8226). Examines how Brazil started to manufacture its own HIV/AIDS drugs in 1997 against the warnings of international drug companies. The effort halved the death rate from AIDS and helped to stabilize the epidemic in this country.

Possible Topics for Student Research

1. Current public and popular perceptions of science.
2. Nuclear research in Latin America.
3. Biotechnology in Latin America.
4. Medical Responses to AIDS and Cholera.
5. Western Science and traditional indigenous knowledge.
6. Training overseas: a useful solution to offsetting the lack of strong local research institutions?
7. Examine the factors that militate against the growth of science out of an autonomous public sphere. What would it take to end Latin American science's secular pattern of dependency on the State?

Australia and the Pacific

David Turnbull and Philip Rehbock

INTRODUCTION

Any examination of non-Western knowledge has to start with a reexamination of Western science and technology and their relationship. All too often in the past it has been assumed that the canonical exemplification of rationality, objectivity, universality and truth is Western science and that technology is the proof of the pudding--it works. The effect of such assumptions is to relegate non-Western knowledge to the merely traditional, local, or pratical category whose only real interest or value is to be collected and added to the Western archive as either exotic or exploitable.

Recent approaches in the sociology of scientific knowledge, anthropology and history of science, feminism, and post-colonialism have provided a new understanding of Western science and technology. Science and technology are not simply pure and applied knowledge they are intimately linked and were created at a particular juncture and at particular sites, that is to say they are local and moreover their supposedly acultural character was coproduced with them. Recognizing the local nature of Western technoscience provides for the possibility of an equitable comparison of knowledge traditions. Ultimately the point of comparing knowledge traditions is to enable indigenous students to discover and appreciate their own knowledge traditions, for non-indigenous students to interrogate Western traditions and for all students to find ways of enabling disparate knowledge traditions to work together to ensure the viability of cultural diversity.

Essential Library Resource:
Selin, H. (ed.), *Encyclopedia of the History of Science, Technology and Medicine in Non-Western Cultures*, 2nd edition (Dordrecht: Kluwer Academic Publishers, 2007).

Journals:
Indigenous Knowledge Monitor
Cultural Survival Quarterly

Elecronic/Internet Resources:
Indkno

Day 1
Introduction: Comparing Knowledge Traditions

Student Reading

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Extended Reading

- Anon. *Science and Indigenous Knowledge*, SciDevNet Science and Development Network, August 2002. On-line address: http://www.scidev.net/dossiers/index.cfm?fuseaction=dossierfulltext&Dossier=7.
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Day 2
Indigenous Mapping

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- Kelly, Jan. "Maori Maps," *Cartographica*, *36* (2) (1999): 1-30.
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Day 3
Pacific Island Navigation

Pacific Island navigation is perhaps the single best example of an organised knowledge system that does not have Western characteristics: there is no writing, no calculation, no compasses. But the Pacific was nonetheless colonized.

Student Reading

- Turnbull, D., *Mapping The World in the Mind: An Investigation of the Unwritten Knowledge of the Micronesian Navigators* (Geelong: Deakin University Press, 1991).

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- Bednarik, Robert, "Seafaring in the Pleistocene." *Cambridge Archaeological Journal*, *13* (1) (2003): 41-66.
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- Turnbull, David. *Masons, Tricksters and Cartographers: Comparative Studies in the Sociology of Scientific and Indigenous Knowledge*, 2nd edition (London: Routledge, 2003), Chapter 4, "Pacific navigation: An Alternative Scientific Tradition."

Day 4
Australian Aboriginal Ecological Knowledge

Student Reading

- Christie, M. J., *Aboriginal Science for the Ecologically Sustainable Future*, National CONSTA Conference of Teachers of Science and Technology, Alice Springs, 1990.
- Helen Watson with the Yolgnu community at Yirrkala and David Wade Chambers, *Singing The Land, Signing The Land* (Geelong: Deakin University Press, 1989).

Extended Reading

- Baker, Richard. *Land Is Life: From Bush to Town. The Story of the Yanyuwa People* (St Leonards NSW: Allen & Unwin, 1999).
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- Johnson, Dianne, *Night Skies of Aboriginal Australia: A Noctuary*, Vol. 47, *Oceania Monographs* (Sydney: University of Sydney, 1998).
- Jones, Rhys and Betty Meehan, "Balmarrk Wana: Big Winds of Arnhemland," in *Windows on Meteorology: Australian Perspectives*, Eric Webb, (ed.) (Melbourne: CSIRO, 1997), pp. 15-19.

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- Williams, N. and G. Baines (eds.), *Traditional Ecological Knowledge: Wisdom for Sustainable Development* (Canberra: Center for Resource and Environmental Studies, 1993).

Day 5
Maori Knowledge

Readings:

- Roberts, Mere, Brad Haami, Richard Benton, Terre Satterfield, Melissa Finucane, Mark Henare, and Manuka Henare, "Whakapapa as a Maori Mental Construct: Some Implications for the Debate over Genetic Modification of Organisms.," *The Contemporary Pacific, 16* (1) (2004): 1-28.
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Pacific Natural History

Student Reading

- Gegeo, David and Karen Watson-Gegeo, ""How We Know": Kwara`Ae Rural Villagers Doing Indigenous Epistemology (the Kwara'ae Genealogy Project, Solomon Islands)," *The Contemporary Pacific*, *13* (1) (2001): 55-88.
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- Davis, Allen, "The Native Knowledge of Chuuk Lagoon," in *Oceanographic History: The Pacific and Beyond*, F. Rehbock and K. Benson (eds.), 1998.

Extended Reading

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- Cox, Paula and Sandra A. Banack, *Islands, Plants and Polynesians: An Introduction to Polynesian Ethnobotany* (Discordes Press, 1991).
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- Johannes, R. E., *Words of the Lagoon: Fishing and Marine Lore in the Palau District of Micronesia*, 1981.
- Krauss, Beatrice H., *Plants in Hawaiian Culture*, 1993.
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  - Vol. 1: *Ocean and Coastal Studies*
  - Vol. 2: *Land Use and Agriculture*
  - Vol. 3: F*auna, Flora, Food and Medicine*
  - Vol. 4: *Education, Language, Patterns and Policy*
- Verran, Helen, "A Postcolonial Moment in Science Studies: Alternative Firing Regimes of Environmental Scientists and Aboriginal Landowners." *Social Studies of Science, 32* (5/6) (2002): 729-62.

Extension Day
Encounters and Interactions

Readings
- Conner, Clifford, *A People's History of Science: Miners, Midwives and "Low Mechanics"* (New York: Nation Books, 2005), Chapter 2.
- Kelly, Jan, "Tuki's Map of New Zealand," *The New Zealand Map Society Journal, 9* (1995): 11-18.
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- Frost, Alan, *The Global Reach of Empire: Britain's Maritime Expansion in the Indian and Pacific Oceans* (Melbourne: Miegunyah Press, 2003).
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and A. Frost, (eds.) (Canberra: Australian Academy of the Humanities, 1989), pp. 169-82.

- Smith, K.V., *Bennelong: The Coming in of the Eora. Sydney Cove 1788-1792* (Sydney: Kangaroo Press, 2001).
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- Williams, Glyndwr, "Tupaia: Polynesian Warrior, Navigator, High Priest– and Artist," in *The Global Eighteenth Century*, Felicity Nussbaum, (ed.) (Baltimore: John Hopkins University Press, 2003), pp. 38-52.

Possible Topics for Student Research

1. Critically evaluate the recent study by the Rural Advancement Foundation International *Conserving Indigenous Knowledge: Integrating Two Systems of Innovation*, commissioned by the United Nations Development Programme.
2. Critically evaluate the role of indigenous knowledge in development.
3. What is the role of indigenous knowledge in intellectual property rights and biodiversity?
4. What was the role of indigenous knowledge in the exploration of Australia?
5. How can reframing Pacific Island navigation benefit contemporary Pacific Islanders?
6. Examine ways in which indigenous mapping and Western mapping techniques like GIS can help indigenous groups in land claims and establishing autonomy.
7. How was indigenous knowledge conceived in the encounters between the peoples of Australia and the Pacific and western explorers?

Japan

Takashi Nishiyama, Sumiko Otsubo, and Walter G. Grunden

INTRODUCTION

This brief study contextualizes key top-down and bottom-up changes in Japanese science, technology, and medicine from about 1600 to the present. Different frames of references are addressed, including global, regional/Asian, national, regional/local, institutional, organizational, and sectional. At the national level, many scholars have focused on some form of artificially constructed "system"—political, economic, social, technological, or environmental—that facilitates transnational comparisons. The technological system, for instance, includes designers, producers, managers, users, distributors, lobbyists, and the like. Studies of medical communities have dealt with human factors (scientists/practitioners, patients, and healthy individuals), as well as non-human factors (other terrestrial/marine organisms, infections, genetic conditions, chemical substances, and environmental changes). This essay also recognizes the importance of "ordinary people" in the historical landscape. It democratizes, racializes, and genderizes human agents of change by focusing partly on women and ethnic minorities within and outside the country.

An important issue to consider is the historical significance of features common to pre-modern and modern Japanese science—for example, the country's geographical setting. While rejecting geographical determinism, we should consider the formative influence of geographical context on the transformation of science. How has geography/topography helped shape the parameters, content, and transmission of science, technology, and medicine into, within, and out of the archipelago? Notably, unlike European or Latin American nations, Japan shared no land borders with other countries; its geography and politics severely restricted entry of expertise and diseases from overseas, especially before the mid-nineteenth century. The country maintained its official policy of isolation and thus remained largely self-contained until the advent of the (political) modern era. Vital formative influences from the Asian continent continued in science (mathematics and astronomy), technology (metallurgy, agriculture, city planning, and porcelain), and medicine (acupuncture, cauterization, and medicinal herbs). But limited contact of Japan with the rest of the world (except for China, Korea, Rh□ky□ islands, and the Netherlands) from the early seventeenth to the mid-nineteenth centuries seems to offer an opportunity for transnational comparisons, especially considering the spread of epidemic and endemic diseases around the world. A study of Japan since 1600 can refer to geographically similar archipelago settings in Asia, such as the Philippines and Indonesia, or the geographically dissimilar setting of the Eurasian continent.

Day 1
Science, Technology, and Medicine in Tokugawa Japan (1600-1867)

A first key issue we consider is the relations between the degree of central political control and the range of diversity in science and medicine in pre-1868 Japan. At least two cases can be cited. The field of mathematics, *wasan*, evidenced different schools of thought, each capitalizing on the multipolar growth of Tokugawa science. Another case in point involves the introduction of smallpox vaccination into the country with flows of technical knowledge from the periphery to the center. The technique, originally imported from China in the mid-1800s, did not become widespread in Japan. But in the early nineteenth century, Russians had brought the new technique to the northernmost frontier of Ezo (Hokkaido), an area mostly inhabited by the ethnic minority of the Ainu rather than ethnic Japanese. The Jennerian inoculation began to receive a wider support in the southern Saga domain after a physician, It□ Genboku, vaccinated a daughter of the local feudal lord in 1849. After studying Chinese medicine, he studied with a German doctor, Phillip von Siebold (employed at a Dutch factory in Nagasaki); in 1858, together with several colleagues, It□ founded the Vaccination Institute in the urban city of Edo where the Shogunate was located.

Relations between science and national security in politically decentralized Tokugawa Japan also merit attention. The Shogunate retained its control over expertise in key fields of studies to preserve peace from threats, real or perceived, from abroad and at home. For instance, the central government heavily regulated castle construction and maintenance in local domains. From the late seventeenth century, the Tokugawa office of Tenmonkata remained in charge of calendar making, astronomical observation, and topographical survey. Tokugawa Yoshimune (1684-1751) encouraged Dutch learning, which included fields of study such as astronomy, cartography, internal medicine, and surgery. Under government sponsorship, In□ Tadataka (1745-1818) conducted a series of coastal surveying/national mapmaking projects—a field of study important to national security. When Siebold was caught trying to take a copy of such a map with him to Germany, authorities deported him for violating a decree of 1828, which prohibited export of such information.

We move on to consider the relations between occupation-based social hierarchy and the transformation of science and medicine. Tokugawa society, following the official doctrine of Neo-Confucianism, consisted of four main classes from the top to bottom: warriors (roughly six to seven percent of the population, although this and other figures varied from domain to domain), farmers (about eighty percent), artisans (about seven percent), and merchants (about seven percent). In theory, medical doctors, along with Buddhist and Shinto priests, actors, artists, prostitutes, and social outcasts, did not fit into this scheme. Questions to ask include: What social ranks did traditional medical doctors occupy in society? Which groups of ordinary people gained wealth and privilege enough to receive medical care from doctors? How did public health policy differ from domain to domain, and why? What kinds of epidemics struck whom, how, when, and where? An issue worth exploring is the relation between religion and medicine. Given that "blood" and "death" meant defilement in Shinto, the surgeon's social status was presumably low. But the ability to cure medical problems brought certain Tokugawa doctors prestige, wealth, and political connections—elevating some physicians to elite status

despite religious stigma. How diverse was the Tokugawa medical community in terms of social status and class as well as family background? How did women, especially midwives, figure in this landscape?

Student Reading

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- Brett L. Walker, "The Early Modern Japanese State and Ainu Vaccinations: Redefining the Body Politic, 1799-1868," *Past and Present*, *163* (1999):121-160.

Extended Reading

- James R. Bartholomew, *The Formation of Science in Japan: Building a Research Tradition* (New Haven and London: Yale University Press, 1993), pp. 9-48.
- Susan Burns, "The Body as Text: Confucianism, Reproduction, and Gender in Early Modern Japan" in Benjamin Elman, Herman Ooms, and John Dunkan, eds., *Rethinking Confucianism: Past and Present in China, Japan, Korea and Vietnam* (Los Angeles: UCLA Asia Pacific Monograph Series, 2002), pp. 178-219.
- Susan B. Hanley, *Everyday Things in Premodern Japan* (Berkeley: University of California Press, 1997).
- Shigehisa Kuriyama, "Between Mind and Eye: Japanese Anatomy in the Eighteenth Century," in Charles Leslie and Allan Young, eds., *Paths to Asian Medical Knowledge* (Berkeley: University of California Press, 1992), pp. 21-43.
- Morris Low, "Medical Representations of the Body in Japan; Gender, Class, and Discourse in the Eighteenth Century," *Annals of Science*, *53* (1996): 345-359.
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Day 2
Rise of Modern Science, Technology, and Medicine, 1860s-1920s

This unit covers how modern science, technology, and medicine developed roughly during the time of the new Meiji government (1868-1912). The first theme is relation between national security on the one hand and transfer of science and technology on the other, both under the centralized political control of the new nation-state. One useful point of reference is the national slogan of "Rich Nation, Strong Army," which provided political, military, and economic leaders with a rallying point amid a series of civil wars. Also faced with threats from the West, the resulting national security policy helped the government dissolve the remnants of the "feudal" political system, brought industrial production under the protection of the Meiji state, and built military strength for external wars that followed. A late-comer to industrialization, and geographically separated from other countries, Japan needed some kind of institutional, artificial framework to facilitate technology transfer from abroad. Questions we can ask in class include: What is "technology transfer"? Why did some efforts bear fruit while some others did not? What are some multiple contingencies that helped produce curious hybrids of foreign and home traits through a culturally nuanced process of technology transfer?

A second theme in this unit centers around these questions: How could a newly formed nation-state construct "modern" science, technology, and medicine at both regional/national and local levels? What is "modernity"? The experience of Japan during 1860s-1920s points to the importance of institutionalization of science, as well as the planned geographical distribution of the research establishments from the center to peripheral areas. As a beacon and capital of modernity, Tokyo hosted both public and private institutions for research and development; it was also the home of many professional societies in science, engineering, and medicine. Experimental stations and especially observatories were established in fairly remote, peripheral areas, while data were sent back to research centers. The establishment of Tokyo Imperial University (1877) was followed by other imperial universities in various regions; technical/training schools were concurrently set up in peripheral areas, often with financial support from local moguls, a process reflecting local tastes of science and engineering (e.g., saké brewing, dyeing). As a result, during this period, the Meiji government established numerous industrial research laboratories and arsenals, and supported formation of new research institutions in the private sector across the country.

A third issue in this unit addresses the social impact of newly introduced modern science on ordinary citizens. Were ethnic minorities, women, elderly and children, and social outcasts discriminated against in receiving benefits of scientific knowledge? One useful case is the medical policy of 1874, which inaugurated the official adoption of Western medicine. This government initiative, deemed more effective in preventing epidemics and treating wounds caused by military strife, helped shape education. Rapid industrialization and resulting urbanization caused new "social problems." The spread of tuberculosis among female factory workers would compromise Japan's major export textile industry. The increase of the mentally unstable, neurasthenics,

alcoholics, and syphilitics in the city were all considered degenerating to society. Social reformers advocated birth control among poor urbanites, who tended to produce more children than they could feed. Opponents, however, were worried that the relatively expensive new technology would spread among the educated middle class instead of the fertile and uneducated masses, resulting in the deprivation of leaders and the decline of national competitiveness. Health was also believed a measure of how civilized a nation was. Thus, conditions such as high fertility and mortality, malnutrition, and leprosy were believed to cast national shame on Japan. Authorities tried to control population quality and quantity, depending on the state needs, through public health policies; people enthusiastically supported, passively conformed, quietly ignored, or actively resisted such initiatives depending on their circumstances.

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- Richard J. Samuels, "*Rich Nation, Strong Army*": National Security and the Technological Transformation of Japan (Ithaca: Cornell University Press, 1994), pp. 33-107.

Extended Reading

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- Susan Burns, "Bodies and Borders: Syphilis, Prostitution, and the Nation in Nineteenth Century Japan," *U.S.-Japan Women's Journal*, English Supplement, *15* (1998): 3-30.
- Susan Burns, "Contemplating Places: The Hospital as Modern Experience in Meiji Japan," in Helen Hardacre and Adam L. Kern (eds.), *New Directions in the Study of Meiji Japan* (Leiden: E. J. Brill, 1997), pp. 702-718.
- Susan Burns, "Constructing the National Body: Public Health and the Nation in Nineteenth-Century Japan," in Timothy Brook and Andre Schmid, (eds.), *Nation Work: Asian Elites and National Identities* (Ann Arbor: The University of Michigan Press, 2000), pp. 17-49.
- Susan Burns, "From 'Leper Villages' to Leprosaria: Public Health, Nationalism and the Culture of Exclusion in Japan," in Alison Bashford and Carolyn Strange, (eds.), *Isolation: Places and Practices of Exclusion* (London: Routledge, 2003), pp. 104-118.
- Gregory Clancey, *Earthquake Nation: The Cultural Politics of Japanese Seismicity, 1868-1930* (Berkeley: University of California Press, 2006).
- Steve J. Ericson, "Importing Locomotives in Meiji Japan: International Business and Technology Transfer in the Railroad Industry," *Osiris, 13* (1998): 129-153.
- Sabine Frühstück, *Colonizing Sex: Sexology and Social Control in Modern Japan* (Berkeley: University of California Press, 2003).

- Aya Homei, "Birth Attendants in Meiji Japan: The Rise of the Biomedical Birth Model and a New Division of Labour," *Social History of Medicine*, *19* (3) (2006) :407-424.
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- Morris F. Low, (ed.), *Building a Modern Japan: Science, Technology, and Medicine in the Meiji Era and Beyond* (New York: Palgrave, 2005).
- Graeme J. N. Gooday and Morris F. Low, "Technology Transfer and Cultural Exchange: Western Scientists and Engineers Encounter Late Tokugawa and Meiji Japan," *Osiris*, *13* (1998): 99-128.
- Tessa Morris-Suzuki, *The Technological Transformation of Japan: From the Seventeenth to the Twenty-First Century* (Cambridge: Cambridge University Press, 1994), pp. 71-142.

Day 3
Science, Technology, Medicine for Colonial Expansion, 1890s-1945

In this unit, we consider how external wars helped develop science, technology, and medicine at home and abroad from the time of the Sino-Japanese War (1894-95) to the end of World War II in 1945. At a simplistic level, external war differs markedly from domestic civil war, for the former is far less demoralizing and physically less devastating at home than the latter, regardless of the outcome. Notably, Japan's external wars took place every ten years: first against China (1894-1895), then against Russia (1904-05), and later against the Triple Alliance in World War I (1914-18). As a victorious imperial power that remained physically unscathed, Japan benefited from waves of postwar economic booms during these decades. Among the beneficiaries of the country's territorial and economic expansion were light and heavy industries. For instance, the government-run Yawata Steelworks, beginning operations in 1901, received a continuous supply of iron ore from the Daye Mine of the Qing dynasty in China.

A related issue worth exploring is what a nation-state could do to construct imperialism abroad and at home. What are some roles of science, technology, and medicine in the process? Japan's annexations of Taiwan (1895), Korea (1910), and later Manchuria (1931) seem to offer a meaningful case study. Its colonial policy, followed by military escalation, helped war-related business conglomerates expand geographically in Asia. Japan's colonial expansion induced faster and wider spread of sexually transmitted disease within the occupied areas. The quality and quantity of the Japanese citizens beyond the country's shores became official concerns as modern Japan began to rule and populate its new, expanding multi-ethnic empire. The territorial expansion helped develop colonial medicine, including research on bodily differences of various ethnic groups and tropical diseases. Especially into the 1940s, expansionist wars also presented the opportunity to develop more lethal, less expensive chemical and biological weapons against combatants and non-combatants alike in China.

A third issue of historical importance is the impact of modern science on center-periphery power relationships in the world during the age of imperialism. By the late 1910s, Japan had escaped colonization and emerged as a colonizer in Asia through massive industrialization and militarization. As a non-Western colonial power in Asia, Japan seems to offer a useful example to illuminate the volume, direction(s), and contingencies influencing the complex traffic of scientific knowledge in the world. By no means a mere consumer of technical knowledge of the West, Japan emerged as a producer and emitter of modern scientific knowledge within its Asian empire by the early twentieth century. Besides, those under Japan's colonial rule received scientific information not only from Japan but also from the West. How did these complex relationships figure in the circulation of scientific, technological, and medical knowledge around the world? Scientific ideas purportedly flew from the center to the periphery, but we remain relatively unfamiliar with how ideas circulated within the "peripheries" of knowledge production and how the periphery attempted to transform itself into the center.

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Day 4
Science, Technology, and Medicine for War, 1930-45

In this unit we explore the relationship of science to war that became paramount during these fifteen years. The rise of militarism underlay Japan's road to war from its invasion of Manchuria in 1931 to the Pearl Harbor attack in 1941. Healthy citizens, male and female, were mobilized for total war until military defeat in August 1945. In this context, for instance, the National Eugenics Law and National Physical Strength Law were passed in 1940 to regulate the health of Japanese population before and after birth. These initiatives attested to the importance of women's roles in reproduction and nurturing for a nation at war. Important topics relating to science during 1930-45 include Japan's own research for the development of an atomic bomb, as well as the infamous Unit 731 that experimented on captured human subjects in China for the development of biological and chemical weapons.

Another issue of historical importance is why and how Japan mostly failed to develop "Big Science" for modern warfare. A point to note is that, especially when compared to other industrialized countries, Japan lacked an effective central policy-making body for science and technology. Many examples could point to disintegrating, demoralizing effects of sectionalism. Aside from the Army-Navy inter-service rivalry, the Army in particular interfered in civilian agencies; government agencies and offices were established one after another to provide oversight for funding, mobilization, and administration of both public and private research institutions. Sectionalism was not unique to wartime Japan, but what contrasts with comparable cases in other countries was the extent and duration of the quiet, demoralizing subterranean wars among sections at home while fighting against foreign enemies. What factors help explain this? One revealing case involves Miyamoto Takenosuke, an engineer, and his proposal for the creation of a "New Order of Science and Technology" in the 1930s. In his view, a "Technology Agency" was to be established as an administrative center

for coordinating scientific research on a national scale, and more importantly, to act as a liaison between civilian and military research institutions. Bureaucratic sectionalism within the top levels of the government, however, impeded this agenda, and the military services, especially the Army, further complicated matters by refusing to submit their research institutions to civilian control or domination by civilian scientists, as the New Order legislation proposed. The initiative bore little fruit as a result. By the time the Technology Agency (*Gijutsu-In*) officially opened in early 1942, its original purpose as a central office to enforce science and technology policy had been virtually eliminated. Where once Miyamoto and the technocratic lobby had envisioned something akin to the Office of Scientific Research and Development that emerged in the United States during the war, the Technology Agency, in fact, became little more than an office of the army charged with oversight of aviation research and development.

Next, we move on to consider some consequences of the ineffective science policy of wartime Japan. Comparisons of different fields of science in the country can help us examine the issue. For example, advanced weapons projects could include radar, long-range missiles, and nuclear weapons, all of which required massive funding, as well as the coordination and collaboration of various public, private, military, and civilian agencies. In wartime Japan, these projects stumbled along, competing for resources against numerous other research and development projects with far less potential for contributing to the war effort. As a result, radar technology did not progress much further than its state at the outset of the war, and research in nuclear weapons development remained at a comparatively rudimentary stage. In the area of weapons of mass destruction, Japan excelled only in the development of biological warfare. Why did some fields advance more than others, and other than sectionalism, what factors can explain the variance?

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Day 5

Science, Technology, and Medicine for Peace, 1945-60s

This unit examines the impact of foreign-power occupation on the (re)shaping of science, technology, and medicine for twenty years or so after the end of World War II. One way to explore this issue is to examine Japan within a bi-national or broader international context; for instance, the experience of postwar Japan and that of Germany seem comparable in many ways, for both came under the Allied Occupation. The presence of the United States was more pronounced in Japan, playing a formative role in the politicization of professional societies, the rise of the Left, and changing landscape of higher education. One notable difference is the presence or absence of brain drain. Unlike many German scientists and engineers who emigrated after the war (e.g., architect of the Apollo Program, Wernher von Braun), almost all Japanese (with few exceptions including female physicist, Yuasa Toshiko) were contained in their country during the U.S. Occupation years of 1945-52. They could not simply walk or swim across national borders into neighboring countries, which remained deeply hostile given Japan's wartime aggression. What are some push and pull factors that could encourage or discourage the emigration of scientists and engineers in peacetime?

For our purposes, the year 1945 serves as a convenient division between war and peace, and between the country's prewar and postwar science policies. One topic of discussion is whether or not the U.S. Occupation policy sped up or retarded the process of postwar reconstruction in science and technology. What fields of science, technology, and medicine in Japan benefited more than others from the U.S. Occupation, and why? A key administration was the Supreme Commander of Allied Powers (SCAP), which had the mission to demilitarize and democratize the war-torn Japan. In aircraft and naval engineering, SCAP (at least temporarily) forbade research and development, as well as production of all types of armaments and munitions, including warships and all aircraft. Equally hit was the field of nuclear physics. At one point, the authority's relentless pursuit of mission led to the destruction of four cyclotrons (nuclear particle separators) then available in Japan—one dumped into the Bay of Tokyo, which astonished those in the Riken's Nuclear Physics laboratory and the world scientific community. Furthermore, the war separated Japan's scientific communities at least temporarily from their counterparts around the world. How were the ties restored and with what consequences within the context of the Cold War? Certain individuals seem to have been crucial, one being Harry C. Kelly, a physicist who had worked at the Radiation Laboratory at MIT during the war. Recruited into the U.S. Occupation bureaucracy, Kelly served well as a liaison; he helped soften the early, rather draconian Occupation policy and earned the trust of his Japanese colleagues.

Next, we consider the impact of the end of militarism at home and imperialism abroad. Successful spin-off of wartime science and technology became readily observable in most cases by the late 1960s, especially when manifested as visible objects. Cases in point include the use of the Mitsubishi Zero fighter's aero-engine technology in postwar Nissan automobiles, and civilian application of wartime aeronautical technology in the development of the *Shinkansen* high-speed bullet train. More nebulous, thus more difficult to

explicate, were cultural elements of wartime science, technology, and medicine that survived beyond 1952. Recent scholarship has pointed out continuity in personnel and organization in trans-World War II Japan, but what helped determine which wartime elements (e.g., ideology, policy, system, etc.) survived into, or ceased to exist in, the following decades and with what consequences? What happened to medical science and system of Japanese empire in Asia after the war's end in 1945? What factors successfully turned—and more importantly, what factors failed to turn—the military defeat into "creative destruction"? How did female scientists benefit from the Occupation policy that opened the door for their higher education?

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Day 6
Science, Technology, and Medicine Since 1952

Our first focus in this unit is how Japan has developed "Big Science" and big business at home since the time of the U.S. Occupation. One challenge the country faced was how to build a prosperous, peace-oriented, industrialized economy without colonies abroad. A crucial crutch for the country's speedy recovery was the Korean War. Japan, now a reliable Cold War ally in Asia, became a logistically convenient supplier of vehicles and electronics to the United States and benefited from U.S. war procurement needs. Japan's postwar high-speed industrial recovery and economic growth followed, particularly in heavy industries (shipbuilding, steel, electronics, and automobile industries) from the late 1950s through the 1960s. What supported this transformation included business leadership, ideology, female labor force, and managerial techniques (e.g., quality control and rationalization) in the private sector; and top-down government policies, export-driven economic structure, and social networks of information, among other factors, in the public sector. The three agencies that dominated science policy during this period were the Science and Technology Agency, the Science and Culture Division of the Ministry of Education, and the Ministry of International Trade and Industry. Policies favored the promotion of "big" national projects, such as the development of the nuclear energy industry, outer-space rocket/satellite development, and exploitation of ocean resources, which arguably ushered in the age of "Big Science" in Japan at last.

Next, we explore some negative consequences of the rapid economic growth of postwar Japan. What were some cases of environmental pollution, and how did ordinary citizens respond in their local communities? How did business corporations and the national government try to solve industrial pollution while vigorously promoting the country's fast economic development? How did scientists respond, and what were their responsibilities, to nuclear pollution in the only country in the world that had come under two atomic-bomb attacks? One topic of interest in this line of questioning is the public roles of women concerned about birth defects of their young and/or yet-to-be-born children. Some women, particularly ordinary housewives, were active in promoting safer nuclear power plants, materials used in housing and public facilities, and residual agricultural chemicals in imported and domestically produced foodstuffs. Many women remained reluctant to imbibe chemical substances; for instance, contrary to feminist activism elsewhere, they opposed deregulation and use of low-dose oral contraceptives as late as the 1990s.

Finally, this unit deals with Japan's efforts to use science and technology politically in the international arena during and after the Cold War. A bi-national framework seems useful for our study. For instance, the U.S.-Japanese alliance has promoted cooperation in applied science and technology since 1952.

Cases in point include United States-Japan Cooperative Programs in Natural Resources (1964), Medical Science (1965), and Brain Research (2000); other bilateral agreements include U.S.-Japan Environmental Protection Agreement (1975) and U.S.-Japan Science and Technology Agreement (1979). In a global framework, Japan became a member of the International Atomic Energy Agency (1957) and hosted the international forum for cooperation in the field of nuclear science (1965). Japan's formative role around the globe shows in environmental science, as in the formation of the Kyoto Protocol to the United Nations Framework Convention on Climate Change (1997). Questions worth asking include: How and why did Japan mobilize science, technology, and medicine to promote internationalism during and after the Cold War, and what were some limits in doing so? Is internationalization of science chiefly a product of World War II and/or the Cold War? How can the seemingly irreconcilable tension between "nationalism" and "internationalism" in science be solved? How have Japan's efforts been perceived in the rest of the world?

Student Reading

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Extended Reading

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Possible Topics for Student Research

1. What is "modern" science/technology/medicine? Can it be independent from political or economic modernity? If so, how and why?
2. What facilitates the diffusion of scientific knowledge among regions or nations? How does knowledge transfer differ from knowledge diffusion?
3. How do such factors as class, gender, and race/ethnicity figure in the formation of scientific, technological, and medical knowledge?
4. What are some characteristics of "Big Science" in our modern world? To what extent did Japan succeed in its efforts during and after World War II, and why?
5. What are some roles of scientific communities in forming nationalism and internationalism in modern Japan?

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Jorge Cañizares-Esguerra is the Alice Drysdale Sheffield Professor of History at the University of Texas. He has held several prestigious fellowships at Brown, Princeton, Harvard, the Huntington, and U.Texas. His "New World, New Stars: Patriotic Astrology and the Invention of Indian and Creole Bodies, 1600-1650" (AHR, February, 1999) won the 1999-2001 best article award from the Forum in the History of the Human Sciences of the History of Science Society. His *How to Write the History of the New World: Histories, Epistemologies, and Identities in the Eighteenth-century Atlantic World* (Stanford University Press, 2001) won two book awards from the American Historical Association in 2001 (The Atlantic History and the John Edwin Fagg Prizes). It was cited in 2001 in TLS, the Independent (London), and the Economist among the best books of the year. His recent *Puritan Conquistadors* (Stanford, 2006) received the 2007 Honorable Mention of the biannual Murdo MacLeod Book Prize of The Latin American and Caribbean Section of the Southern Historical Association. He is also the author of *Nature Empire and Nation* (Stanford 2006) and *The Atlantic in Global History* (coedited with Erik Seeman) Prentice Hall, 2006).

Walter E. Grunden is an Associate Professor of History at Bowling Green State University in Ohio. He received his Ph.D. from the University of California, Santa Barbara, in 1998, and the M.A. from the Ohio State University in 1990. He is the author of *Secret Weapons & World War II: Japan in the Shadow of Big Science* (University Press of Kansas, 2005), as well as articles focusing on nuclear weapons history. He has been awarded research grants from the Social Science Research Council, the Japan Society for the Promotion of Science, the Association for Asian Studies Northeast Asia Council, the U.S. Department of Education, and the Center for Japanese Studies

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Takashi Nishiyama is assistant professor in the Department of History at the State University of New York at Brockport. He completed his Ph. D from the Ohio State University, and has been a Visiting Researcher in the Research Center for Advanced Science and Technology at Tokyo University and a postdoctoral researcher at the Dibner Institute for the History of Science and Technology, Massachusetts Institute of Technology. Among his publications in Japanese and English is "War, Peace, and Non-Weapons Technology: The Japanese National Railways and Products of Defeat, 1880s-1950s," in *Technology and Culture, 48* (2) (April 2007): 286-302. His current research focuses on the historical relationship of technology to war and peace in Japan during the twentieth century.

Sumiko Otsubo completed her Ph.D. at Ohio State University. She has been a postdoctoral fellow at the Reischauer Institute of Japanese Studies, Harvard University. Currently she is Associate Professor in the Department of History, Metropolitan State University in St. Paul, Minnesota. Her publications include "Between Two Worlds: Yamanouchi Shigeo and Eugenics in Early Twentieth Century Japan," *Annals of Science*, *62* (2) (April 2005): 205-231, and "Engendering Eugenics: Feminists and Marriage Restriction Legislation in the 1920s," in Barbara Molony and Kathleen S. Uno, (eds.), *Gendering Modern Japanese History* (Cambridge, MA: Harvard University

Press, 2005), pp. 225-258.

Philip F. Rehbock earned his B.A. in Economics at Stanford University in 1965. He received his Ph.D. in History of Science from Johns Hopkins University in 1975 and taught subsequently at the University of Hawaii. His principal research focus was the history of natural history in 19th-century Britain, with special emphasis on the development of marine biology, ecology and biogeography. His first book, *The Philosophical Naturalists: Themes in Early 19th-Century British Biology,* addressed the role of idealist or "transcendental" philosophies in these sciences. In addition, he edited numerous volumes, including *At Sea with the Scientifics: The* Challenger *Letters of Joseph Matkin* (1987); *Oceanographic History: The Pacific and Beyond* (2002); and, in collabotation with Roy MacLeod, *Nature in its Greatest Extent: Western Science in the Pacific* (1988) and *Darwin's Laboratory: Evolutionary Theory and Natural History in the Pacific* (1995).

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David Turnbull teaches at Deakin University in Geelong, Australia, where he has developed numerous educational materials on sociology of science, technoscience and aboriginal knowledge (especially maps and Micronesian navigation). His 1989 book, *Maps Are Territories; Science is an Atlas* (reprinted by Univ. of Chicago Press, 1993), reflects his enduring concerns for and expertise in maps, representations of knowledge and their use in social and political contexts. He is also co-author of *Life Among the Scientists: An Anthropological Study of an Australian Scientific Community* (1989). His current research/activity focuses on indigenous and local knowledge and the interaction of knowledge traditions, mapping and rights/power for indigenous peoples.